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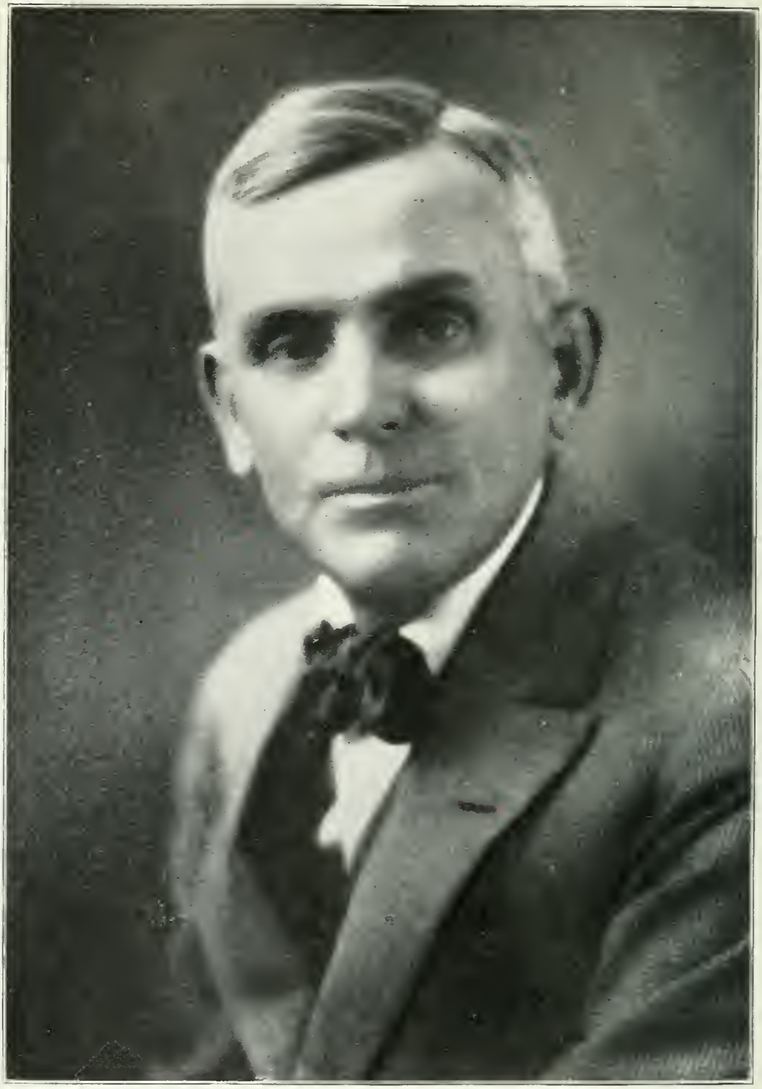

CHARLES B. BURDICK,
President of the Western Society of Engineers, 1918.

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ENGINEERING DATA NECESSARY FOR AN ELECTRIC RATE DETERMINATION

Bert H. Peck, Assoc. W. S. E.*

Presented November 26, 1917.

A regulatory body in establishing rates for utility service must give consideration to practically the entire scope of the utility's operations. It must consider and fix, at least between limits, the value of its property devoted to utility service; it must analyse its expenses of operation; it must consider the character of the enterprise, its stability, the character of the community served and other similar elements for the purpose of fixing a rate of return; the Commission must inquire as to the character of the property and its suitability in order to properly gauge the annual depreciation; in determining upon a schedule of rates inquiry must be made as to the effect which rates of the character proposed will have upon the revenues and the business development in the future. All of these elements must be considered in every case, although more closely and carefully in some instances than in others. Many of these features are scarcely touched upon in the usual discussions of regulatory problems, although many of them merit as serious consideration, if not more serious consideration than the questions of valuation theory which appear to have held the center of the stage up to the present time.

These many and varied features of the inquiry may be classified as follows:

1. Value of the property.
2. Operating expense.
3. Character of the enterprise.
4. Local conditions affecting the operation and development of the business.
5. Conditions which determine the accruing depreciation.
6. Effect of proposed forms of rates.

In the following I shall take up these various features and without going into detail attempt to give an idea as to the methods followed by the engineering staff of a utility commission in carrying out its investigations regarding the engineering features of these

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various problems and presenting its conclusions for the consideration of the Commission.

So much has been written and said regarding the valuation of utilities that one hesitates to approach a subject which is even kindred to it for fear of repeating what has already been said many times. It is not my intention to touch upon this subject from the standpoint of unit costs, overhead costs, going value and other weather beaten standpoints but rather to discuss the other engineering elements which too often receive minor consideration. While much has been written by authorities associated with utility interests and with the direct public interests regarding the theories and practice of engineering valuation, but little has been brought out as to the functions which the engineering staff of a regulatory body may be expected to perform. In fact, from reading previous discussions, one is necessarily led to conclude that the duties of the engineers reporting directly to a utility commission are of a perfunctory nature and contribute little which is of real value to the proceeding. From several years of association with a Commission which constantly has before it actions involving rate analyses as well as from previous experience with utilities and with municipalities, I believe I may offer some information and present some ideas which will prove of general interest.

The matter of valuation naturally presents itself as a question of prime importance in a rate-making proceeding, and it is, without question, a matter of importance although perhaps it scarcely merits the full prominence which is usually accorded it.

During the progress of a utility rate investigation the Illinois Public Utilities Commission has usually directed its engineering staff to prepare and submit in the record estimates as to several phases of the costs of utility property, and has indicated that it desires estimates of original cost, reproduction cost and normal reproduction cost. Court decisions have clearly indicated that, in passing upon the values of utility property, inquiries along these several lines may properly be conducted. Having been called upon for estimates of this nature the engineering staff of the Illinois Commission has worked out certain methods and developed certain plans of attacking the problems which I will briefly discuss.

The original cost estimate is a computation representing as nearly as may be the original cost of the identical items of plant and equipment comprised in the property of the utility. In other words, it is an estimate of the amount which the equipment accounts of a utility would show if accounting methods were infallible and if these accounts had been kept accurately without change of principle since the inception of the property. At first thought, the preparation of such an estimate would appear most difficult but we have not found it so except in some few particulars. The inventory of the existing property is of course available for furnishing the quantities of plant to be used. Most utilities have preserved at least to a reasonable extent the vouchers and bills showing expenditures

for material. There is usually some employee connected with the property who is acquainted with conditions which have existed for many years past. Vouchers and payrolls are available showing wage rates over a period of years. Thus most of the elements entering into unit cost determinations are available. Oftentimes records will be missing for some intervals during the time the property has been in the course of development and construction, but the facts prevailing during such periods may usually be inferred with reasonable accuracy from a study of the periods either side of that which is missing. Records of metal prices are available from metal markets reports. The manufacturers who originally furnished equipment are frequently able to give information regarding the original selling prices of equipment and very often are able to recall the circumstances and conditions surrounding its original installation.

From experience gained with such estimates prepared for numerous cases involving utilities of various sizes and in different locations, I am of the belief that sufficient data usually exists to enable the preparation of estimates which, if carefully prepared, will reflect the actual cost of property nearly as accurately as carefully kept accounts and with greater accuracy than accounts carelessly kept or in which the accounting system has been frequently changed during the years of construction.

For purposes of preparing estimates of this nature we have found it particularly helpful to obtain and keep records of the time required for construction operations such as setting poles, stringing wire, etc. Such construction records may be obtained from work-order systems and should always be accompanied by statements showing the prevailing conditions such as the character of teaming service, the hours worked per day, number, and grade of men composing gangs, the character of soil encountered, etc. Such records are very useful in applying different wage scales prevailing at different periods.

In addition to data obtainable regarding particular conditions for the interested utility, cost data for other utilities may be consulted to fill in gaps and to verify conclusions. Curves may be plotted showing trend prices for material during the course of years. In applying data in this manner extreme caution must be used to properly care for varying freight rates and delivery points and, above all, for varying conditions which may surround the work of construction.

The original cost estimate operates to meet many usual criticisms of valuations. It enables the consideration of many elements which have materially influenced the actual investment in the property in question, and which cannot receive consideration in a valuation prepared upon reproduction theories. Thus, in a recent instance it appeared that a building addition required the installation of roof steel over boilers and engines in operation, and this steel work was included in an original cost estimate at a price

of 10 cents per pound, where a reproduction figure in excess of 6 cents per pound could not have been justified.

I wish to avoid an impression that the preparation of an estimate of original cost such as I have described is in any degree akin to an accounting problem. The estimate is based upon an inventory and is distinctly an engineering estimate based upon engineering data and carried out by engineering methods.

In our consideration of original cost estimates we have estimated accrued depreciation in a manner as described later.

In what we have termed our reproduction cost estimate we have assumed a strictly reproduction program. Our estimates have been based upon the assumption that no plant is in existence and that one is to be constructed in the manner that good judgment, good engineering and consistent application would dictate. In this case also the inventory of the existing property is available.

The preparation of the reproduction cost estimate offers in some respects an easier and in some respects a more difficult problem than the original cost estimate. Cost records are more easily obtainable but, particularly for units of considerable size, these records have the disadvantage of being quotations instead of actual transactions. The exact physical conditions of construction are discernible to a greater extent than in the original cost calculation. As previously indicated, a strict reproduction plan is adhered to which will deliver the property completed and ready for operation as of the date of the inventory. This necessitates mapping out a construction program for wholesale construction requirements and the determination of a program of purchase which enable a determination of prices applicable for materials many of which are subject to wide and rapid market fluctuations. This estimate may be considered as practically duplicating an estimate which might be prepared by an engineering department or a consulting engineer for an extensive piece of construction except that it has the advantage of a reasonably accurate inventory of materials which will be used while a construction estimate must necessarily allow for a greater variation in material quantities, due to the requirement of more or less construction than originally anticipated, and due to the inability to accurately predict many conditions which will materially influence the character of construction which will be required.

In a reproduction cost estimate, as we use the term, meaning strict reproduction, the possibility and profit of contracting certain portions of the work must be considered, the character of available labor must be studied and methods must be outlined which will result in an efficient and economical construction program.

In forming an opinion as to the accuracy of the reproduction estimate so prepared, we do not have as great opportunity to check our results as with the original cost estimate since properties are seldom built under strictly reproduction conditions. However, it would appear that such an estimate would be very nearly as accurate as the original cost estimate, provided care is exercised.

Data as to the original cost of certain items of equipment may be used in determining their reproduction cost, if consideration be given to variation in the elements which affect the cost as between the different dates, and, provided sufficient consideration is given to the conditions which originally prevailed. If one will take the time to study variations in costs with market and labor conditions, proper conclusions may be drawn in many cases. For such purposes, studies are necessary of the construction details of various items of equipment of various manufacturers and the prevailing price tendencies of certain manufacturers' products in order that costs as of different dates and different types of equipment may be compared. This is true of any valuation, no matter the basis upon which it may be compiled. Thus, to compare the prices of certain types of boilers or electric meters without a knowledge of their construction, and (if I may coin a phrase) their "price-characteristics," would lead to serious errors. For this reason I have always looked askance at prices "per kilowatt" or per "horse-power" except as furnishing a check or verification of a general character. I recall in a recent valuation proceeding an attempt to fix a value of utility property by a "per kilowatt" comparison with the property in Madison, Wisconsin, valued several years ago by the Wisconsin Commission. Knowing both properties, one could appreciate their striking dissimilarity. I believe such comparisons may be proper if made by a competent person familiar with the subject and with the properties to be compared, but not otherwise.

In what we have termed our normal reproduction cost estimate we endeavor to eliminate those elements of equipment or cost appearing in the strictly reproduction estimate which may cause the latter to reflect results either abnormally high or abnormally low. As regards abnormal equipment, I mean such equipment as conditions indicate is unsuited to the requirements. By abnormal prices, I mean those prices which, due to abnormal market or purchasing conditions, do not truthfully reflect a reasonable result. In the preparation of our normal reproduction estimate we are not governed by rigid adherence to the inventory, although a departure into the realm of speculation is not intended. If equipment of a certain type is no longer in general use for the purpose considered, a more modern type may be substituted, as in the case of electric meters no longer manufactured. In considering unit prices an average over a suitable period is used for materials which fluctuate widely such as copper and iron. In such an estimate present-day abnormal prices of equipment would hardly be given full consideration except as contributing to the average. Abnormal construction methods, which might be necessary for the reconstruction of the property, caused by conditions which would not usually prevail, are eliminated in the preparation of this estimate. An effort is made to co-ordinate the entire estimate so that, in its completed form, it will represent the present normal cost of building the

property in question, assuming present normal market, labor, and physical conditions.

In our normal reproduction estimate a computation of accrued depreciation is also presented.

It may appear that the preparation of three such estimates of the character which have been described will operate to further becloud the issues which too often are unnecessarily hazy. The time required is certainly greater than would be required for one estimate of cost but the situation as a whole may be considerably clarified. Many engineers in preparing valuations for rate-making purposes are inclined to over-step the boundaries of strict engineering practise because they so well recognize many factors which it seems unfair to entirely disregard. Thus, an engineer familiar with extraordinary conditions which may have prevailed in the past development of the property may feel that it is unfair to the company to let them pass without notice even though his valuation may be prepared upon the reproduction basis. Thus, he may modify his engineering judgment by what he considers to be but ordinary justice. By the method which I have just discussed the engineer is given opportunity to take these things into full account and furthermore they are labeled so that the judicial authority will see how they have been given consideration and to what degree they may properly influence a judgment as to ultimate values.

If but one estimate were to be prepared and that upon the reproduction basis, a careful and painstaking engineer would wish as complete data as to the conditions surrounding the original installation as were available, and would also wish to know the original costs of equipment, so far as such information might be secured. Thus, even though preparing a reproduction valuation he will usually secure all data necessary for his original and normal estimates. The compilation of data of this nature into estimate form is not so serious a task as might be anticipated since all available information will have been secured. The preparation of the three estimates enables the engineer to view his problem from three angles and to present his opinion to the judicial authority as sound engineering opinion, rather than as engineering opinions tempered by opinions of economic justice.

In connection with all three valuations the accrued depreciation is estimated. This problem involves a careful study of the characteristics of each individual case. To use so-called life tables indiscriminately in determinations of this nature, in my opinion, offers opportunity for the greatest injustice. The experience of the Commonwealth Edison Company in Chicago demonstrates the utter inapplicability of depreciation estimates which may be very properly applicable to usual conditions prevailing throughout the state. The equipment in the large generating stations of Fisk, Quarry, and Northwest are subject to conditions of depreciation as different from those prevailing in a city of 50,000 population as the conditions under which Marshall Field and Company conducts its business

are different from those prevailing in the department store of a smaller city. Depreciation estimates require the careful analysis of local conditions, of historical data, of present and anticipated load requirements and of maintenance conditions. The preparation of an estimate of accrued depreciation from an engineering standpoint is entirely dissociated and distinct from the question whether accrued depreciation should be deducted from costs new in arriving at fair rate-making values. The former falls within the province of the engineer and the latter is entirely without the engineering province.

Opinions may differ as to the equity of arriving at rate-making values by making deductions for accrued depreciation; similarly, opinions may differ as to the correctness of the straight-line, sinking-fund, or compound-interest methods of estimating its amount, but certainly no doubt can exist that the individual case merits individual consideration and that from the strictly engineering standpoint the problem offers opportunity for, and in justice requires, a thorough study of the full conditions. In our work we have endeavored in estimating total and remaining lives of equipment to be governed primarily by a practical consideration of the conditions which will determine these lives for the particular piece of equipment under consideration. As noted above, this involves not only a cursory inspection of the unit to determine its condition of maintenance and a consultation of leather-bound life-tables, but it involves a study of the complete conditions which the particular equipment is called upon to meet, the degree of satisfaction which it gives, the growth of load which it will be expected to carry, its relation to the other items of equipment with which it must work in conjunction, and all the other questions which the manager of the property must face in reaching a decision as to whether the equipment should be retained or removed. It has been of great interest to me to note the accuracy or inaccuracy of estimates of life which we have been called upon to make and it is only by following these matters up and noting the character of mistakes which are made that one may become more proficient.

The Illinois Utilities Commission has relied upon its Engineering Department to see to it that in rate making cases all information necessary for a determination of the issue is presented in logical the usable form. This does not mean that the Engineering Department has been responsible for the preparation of accounting and financial reports, but only that the engineers of the Commission have seen to it that the reports as presented cover the entire sources of information. It is obvious that a regulatory body in passing upon a matter of such serious moment as the rates which may be charged for utility service must view the matter from many angles. It is necessary that information be available as to the character of the community which is being served, the character and operating characteristics of the system engaged in rendering the service, the efforts which have been put forth to develop the business of the

utility, and the results which these efforts have been able to produce. Information of this character, while to a certain extent de-

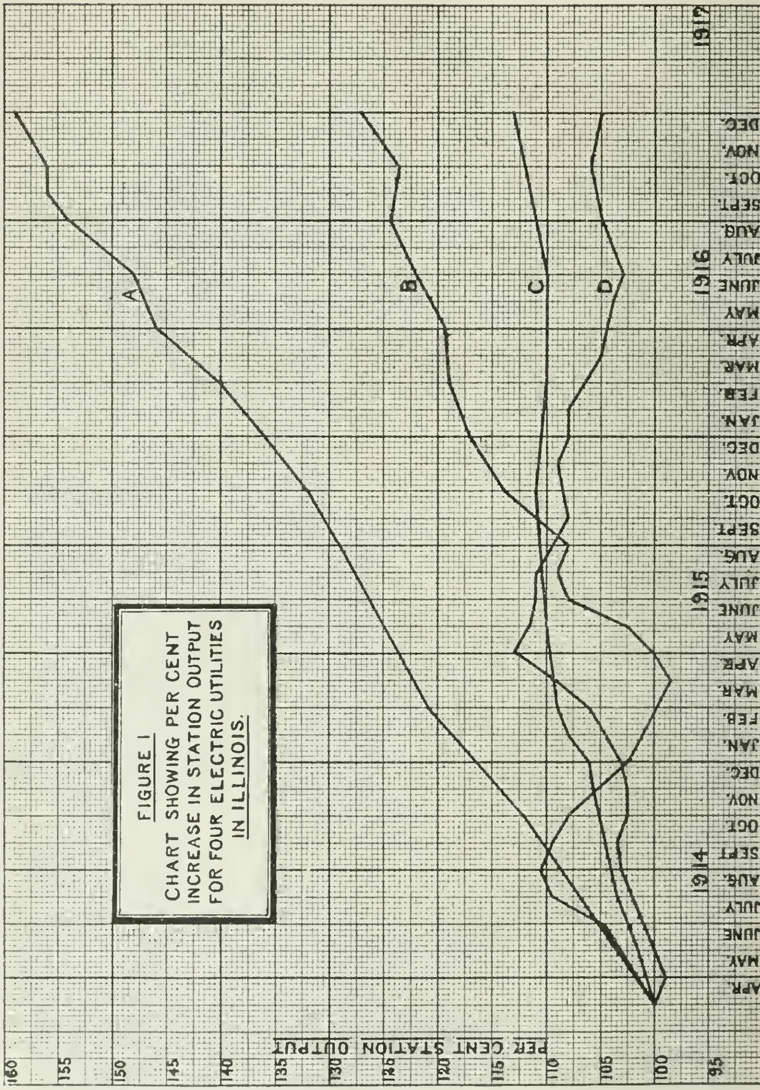

FIGURE I
CHART SHOWING PER CENT INCREASE IN STATION OUTPUT FOR FOUR ELECTRIC UTILITIES IN ILLINOIS.

rivable from accounting reports and exhibits, is nevertheless capable of co-ordination or presentation in form which will make its analysis more simple. Many engineering conclusions may be drawn from

the accounting exhibits. In electric rate cases we have always made it a practise to present to the Commission charts showing by graphical means the growth of the business by yearly periods for as long a time previous as the data may be available. We have analyzed the characteristics of the community from all sources which were available, and have presented in evidence our conclusions as to its character, whether the business of the utility was well developed or poorly developed, and what appeared to be the prospects for further development. These questions are engineering questions in a broad sense, and would appear as quite necessary in conducting a careful consideration of the operations of a public utility. As an illustration of the widely varying characteristics of business and business development, I am showing, in the accompanying *Chart No. 1*, the comparative business development over a period of years of four utilities regarding which the Commission has made investigation. The different degrees of growth of the business will be noted, as will the fact that the business of Company B is very erratic in character. An analysis of the conditions regarding this particular Company will indicate that this erratic business condition is due to the municipal pumping load and an ice plant load, which at times were served by the Company and at other times were not. In the case of Company A the growth of business was very rapid, due to an active campaign which was conducted to avoid a threatened competition in service and to rather extraordinarily low power rates which were a result of this condition. It is obvious that if a regulatory body is to pass upon the question of just and equitable rates, information of this nature must be brought out, if a true appreciation of existing conditions is to be obtained.

In most cases the engineer is apt to look upon the operating expenses and revenues of a utility as a subject coming wholly within the sphere of the accountant. The Illinois Commission in considering these rate problems has instructed its accounting staff to show, in the accounting reports which it may present, the facts and figures just as set forth in the books of the utility, without adjustment or modification, but calling attention to all cases in which poor accounting policy prevails, or an unusual or irregular condition exists. This places before the Commission the fundamental data as shown by the Company's records. The engineering staff of the Commission is then instructed to carefully analyze these accounts, to consider the sources of expense and the methods of operation, to consider the output and all other factors which influence the expenses of operation, and as a result of such analysis, to present to the Commission its opinion, based upon engineering judgment and accounting facts as to the normal expense of utility operation. The necessities which in the past have indicated the wisdom of this policy are many. In the cases of smaller utilities the books of the utility in many cases fail to represent, to even an approximate degree, the expenses of operation. In such cases no distinction is frequently drawn between replacements and repairs. Expenses are indicated as of the period

at which the money is paid out, rather than as of the period during which the material is utilized. In many cases of the smaller utilities the books available are of the most meager character consisting sometimes of but a pocket memorandum book, and we have seen cases in which household expenses have been charged in with the expenses of utility operation. In many cases the utility operator is engaged in two businesses, and the separation of his expense is not indicated on his books. I recall one case in the State of Illinois in which the operator of a utility in addition to utility duties is engaged in the hardware business, is village policeman, and owns and operates a traction engine outfit. His contract for furnishing street lights also covers compensation for village police duties, pumping the village water, heating the village jail and keeping the cross walks free from snow. In another case the utility operator owns a harness shop, a blacksmith shop, and a public garage. It is obvious that an accounting report in cases such as these will leave much to be desired in the matter of a determination of the expenses of utility operation. In the case of larger utilities expenses vary so greatly from year to year, due to unusual maintenance conditions, varying prices of material, labor troubles, and other unusual conditions, that a very careful and detailed analysis of operation expenses is necessary, if a normal amount is to be determined upon. This may not at first appear to be an engineering problem, but we have found that knowledge as to the methods of operation is very necessary in conducting studies of this nature and that engineering knowledge is more adaptable than accounting skill.

In preparing our reports as to normal operating expense the matter of efficiency of operation is a very vital phase of the subject. Some steam plants in Illinois show operating results in the neighborhood of 2¾ pounds of coal per kilowatt-hour generated, and I have heard contentions on the part of responsible operators of utilities in smaller communities that 35 pounds is necessary in the case of a plant giving only midnight service. There is a wide discrepancy between these amounts and a similar wide discrepancy will be found in the expense for fuel per kilowatt-hour, as shown by the records of the utilities. It is clear that a Commission in order to pass upon the equity of operating expenses is going to determine just and equitable rates must know what point between these two extremes offers a just allowance for efficient operation under the conditions which prevail. Data regarding the efficiencies of operation are, of course, also of considerable importance in assisting in a determination of an equitable rate of return.

We have found it necessary, in the case of many of the smaller utilities, to entirely estimate yearly operating expenses in a manner similar to that used by the investigating engineer in reporting upon a proposed project. While a matter of this sort requires some judgment and experience outside the strict realm of applied science, it more nearly pertains to the sphere of the engineer than that of any other profession. It will be seen from my discussion of this matter

thus far that the work of the Commission engineer is very nearly akin to that of the engineer reporting upon a proposed project, and also that of an engineer reporting to men of financial interest upon the possibilities of an existing project, except that the work of the Commission engineer must be in greater detail. This greater detail is necessary for two reasons; first, his reports have something more of an official status and are public documents which may be referred to for purposes other than that which he intended; and, second, he is in some cases subject to cross examination of a most severe character. Both of these facts require that his work shall be upon a firm foundation, supplemented by a careful, unbiased engineering analysis of conditions. Disagreement with these reports is to be expected, and absence of criticisms must be taken as rather a matter of suspicion than of commendation.

Having prepared and presented data of the foregoing nature the engineer has presented practically all information of an engineering nature which may go toward the assistance of the Commission in determining an equitable annual revenue. I have not discussed estimates of annual accruing depreciation, since the engineering factors are so similar to those involved in estimates of accrued depreciation applicable to physical valuations which I have discussed previously. Such estimates of accruing depreciation are, of course, prepared and presented. I do not wish my statement to be taken as indicating that the foregoing information is all which bears upon the matter of a determination of equitable annual revenues, but only that it is a reasonably complete statement of the *engineering* information which may be considered as necessary.

The next kind of information in which the Commission is interested is information bearing upon the character of rates which are best suited to give the revenues which may be determined upon. I am not entirely familiar with the methods which may be followed by other Commissions in approaching this matter, and I believe that the methods of the Illinois Commission are unique and offer some elements of advantage over others which may be employed. The determination of the specific rates applicable in a given instance presents a question having two aspects; first, the question arises as to what character of rates are best suited to meet the conditions prevailing under a given condition; second, the question arises as to specific numerical rates of the character determined upon which will give the certain revenues desired. We hear much discussion now-a-days as to the relative advantages of block rates, step rates, demand rates, etc., and hear many theories advanced which purport to offer a cure-all for every unsatisfactory situation. This matter in particular has always appeared to me as being governed very largely by local conditions; the character of rates which may be applicable to a utility serving a wide territory of diversified interest and character, comprising small villages and large cities must clearly be different from that which is most applicable to a utility operating under but one set of conditions. Likewise the character of rates

which is applicable to a utility having a well organized billing department and a staff of experts well versed in rate matters may be different from that which is applicable to a small utility in which the bills are made out by the operator, whose attention is principally directed to maintaining his engine and boiler operation, purchasing

RESIDENCE CONSUMERS-CONNECTED LOAD AND MONTHLY CONSUMPTION
Year Ended December 31, 1915.

	CONSUMPTION-KW-HRS.	NUMBER OF CONSUMERS Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec	TOTAL CONSUMER: MONTHS	KW-HRS
C.L.(WATTS)400															
	0	1	1	4	6	7	5	11	10	11	8	8	10	82	
*Av.Act.C.L.318	1					2	4	3	5	3	2		2	21	21
	2			1	4	3	6	11	7	3	1			36	72
	3	1	2	7	9	8	10	11	7	3	8	4	3	73	219
	4	3	6	11	11	14	11	5	12	11	6	.5	3	98	392
	5	6	4	3	8	7	7	9	10	8	8	6	7	85	425
	6	6	6	5	4	2	5	7	5	9	12	8	4	75	450
	7	6	4	6	4	5	4	10	7	8	2	6	4	66	462
	8	2	6	6	7	10	9	2	2	3	7	8	8	70	560
	9	5	5	9	6	4	4	6	5	4	7	7	1	63	567
	10	4	7	8	4	4	7	9	5	6	7	5	5	71	710
	11	5	1	1	6	3	4	[illegible]	7	5	4	5	10	53	583
	12	2	6	4	3	8	2	2	3	4	6	3	9	52	624
	13	3	5	2	4	5	2	2	5	4	3	5	2	42	546
	14	2	1	10	5	3	5	2		6	8	7	8	57	798
	15	4	3	1		3	5	3	2	4	2	10	3	40	600
	16	6	10	1	4	2	3	2	5	1	5	9	7	55	880
	17	2	2	5	2	4	2	3	2	2	2	2	5	33	561
	18	2	2	5	4	2	2	2	2	3	3	4	1	32	576
	19	2	1			3	2			1	1	5	7	22	418
	20	5	3	1	3	1			2	3	2	2	4	26	520
	21	4	3	2	1	2		3	2	1	1	4	3	26	546
	22	2	2	2	3		3		2	2	3	1		20	440
	23	3			2		1	1			3		5	15	345
	24		7	1	4		1			2	2.	1	1	19	456
	25	2	1	1		2	1	1		1	1		2	12	300
	26	3	6	2		1				1		2	2	17	442
	27										2	2	1	5	135
	28	1	1			1				1		3	2	9	252
	29	1		1		2			1	1			3	9	261
	30	1					1		1	2		2	1	8	240
	31			1	1						2		2	6	186
	32	1		2			2		1	1				7	224
	33			1									1	2	66
	34	1	1					2			1		1	7	238
	35					1					1			2	70
	36								1		1		2	4	144
	37	1			1		1	1						4	148
	38	1								1		1	1	4	152
	39	1			1									2	78
	40						1							1	40
	41	1												1	41
	43					1						1		2	86
	44										1			1	44
	45		1									1		2	90
	46												1	1	46
	49	1												1	49
	50										1			1	50
	53												1	1	53
	54	1		1										2	108
	58											1	1	2	116
	64												1	1	64
	70													1	70
Total Consumers		92	99	104	108	110	110	110	111	115	123	131	134	1347	
Total Consumption		1470	1368	1212	1181	1102	1065	875	939	1165	1425	1726	2026		15564

Fig. 2

his supplies and personally carrying out the many diversified demands of his property. The point which I am attempting to make is that each situation requires a study by itself, that the needs of the community oftentimes go a long way in determining the character of rate which is most applicable and that the subject is of sufficiently vital importance to well merit an extensive and careful

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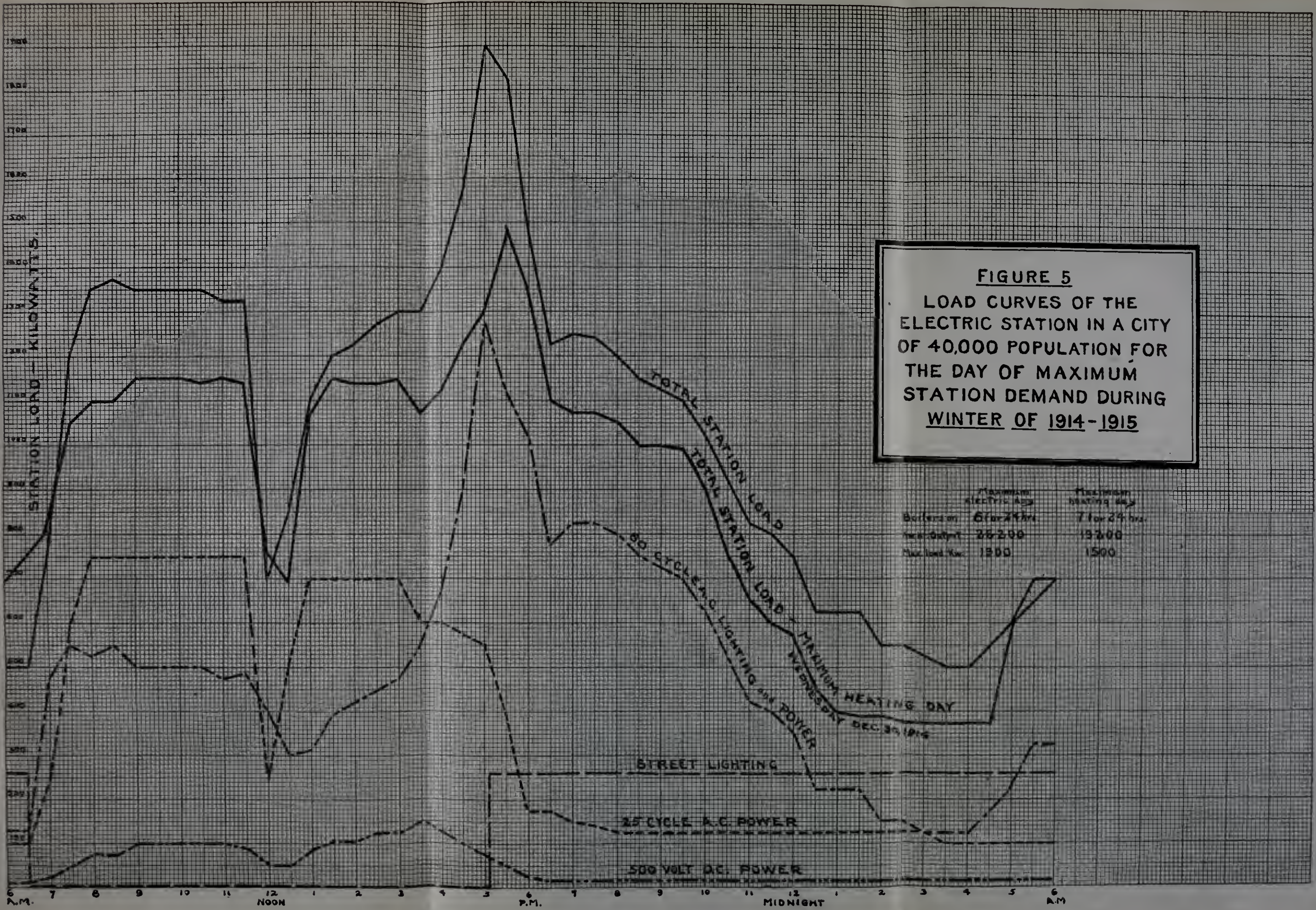

FIGURE 5
LOAD CURVES OF THE ELECTRIC STATION IN A CITY OF 40,000 POPULATION FOR THE DAY OF MAXIMUM STATION DEMAND DURING WINTER OF 1914-1915

consideration of all factors which have to do with it. The Illinois Commission early realized this fact and has always endeavored to secure opinions from the utility involved, from responsible representatives of the community concerned, and from its own experts as to the character of the rate which is best suited to the particular

Table showing the Consumer-Months and Kilowatt-Hour Consumptions of Business Consumers.

Kilowatt-hours monthly consumption per consumer.	Consumer-months	Total kilowatt-hours
0-5	1828	4296
6	252	1512
7	302	2114
8	276	2208
9	318	2862
10	287	2870
11-20	2025	30297
21-30	1179	30096
31-50	1369	53972
50-100	1623	116381
101-200	1261	179558
201-and over	1225	634060
Total	11945	1060226

Figure 3 showing Tabulation of Consumption Data necessary for determination of Revenue from a Step or Block Rate having a Charge for Energy only.

conditions which prevail. The methods by which this information may be presented to the Commission were at first subjects of quandary. If complete testimony were taken regarding valuations and operating expenses and the Commission entered a finding as to the total annual revenues to be allowed, and then reopened the case for the purpose of taking testimony as to the character of rates best suited, the case would be unduly prolonged. If a finding were entered as to the revenues and a determination of the rates left with a utility, one of the principal sources of controversy would still remain. After considerable consideration of this entire matter, the Commission determined upon the plan of instructing its engineering staff to present in the record a schedule of rates which should give

a revenue of an amount which might be indicated or assumed by the engineers. This necessitates that the engineering staff shall assume a valuation of the property, shall assume a rate of return, shall assume an amount of operating expense, and based upon these assumptions compute an amount of annual revenue and develop a schedule of rates which will meet it. This results in bringing into the record a specific character of rate schedule for discussion. It possesses the disadvantage from the witness' standpoint of compelling a number of assumptions which are somewhat without the range of his jurisdiction, and in a sense results in putting his testimony up for the sole purpose of being shot at. It has, however, proved successful for the purpose for which it was intended, namely,

Table showing the Consumer-Months and Kilowatt-hours Consumption of Business Consumers.

Hours Use of Maximum Demand.	Consumer-Months.	Total kilowatt-hours.
First 30 hrs. use	4074	42210
Next 30 hrs. use	2627	82954
Excess over 60 hrs.	5244	935062
Total	11945	1060226

Figure 4 showing tabulation of consumption data necessary for determination of revenue from a Wright maximum demand rate.

the securing of expressions of opinion by all parties concerned as to the best character of rate to meet a given condition.

The second phase of the subject in which the Commission is interested, namely, the numerical determination of a specific rate which will give a certain definite revenue, necessitates the introduction of consumer data to which a given rate schedule may be applied. These data are taken from the books of the utility by the accountants of the Commission who arrange and tabulate them in such form that they are applicable for the purposes intended. The working out of these forms and tabulations presented a pioneer field and in handling the problem the engineering and accounting staffs of the Commission collaborated, with the result that a form was developed as shown in Fig. 2, which is a tabulation taken from an actual record placed before the Commission in a rate making pro-

ceeding. The data must be tabulated in such a manner that any form of rates may be applied to it. The Commission, in working out its schedule of rates, has relied upon its engineers for a computation of revenue which a given rate will develop. A superficial consideration will indicate that impracticability of applying a given rate to a total year's bills by multiplying each bill separately, and it was therefore necessary to develop a system whereby the revenue could be rapidly computed, and changes contemplated in a schedule could be readily adopted without an entire recomputation. Having secured a complete tabulation of consumer data by the tabular means shown in Fig. 2, these data are worked up in the form of a table shown in Fig. 3. A table of this form is applicable only to a block or step schedule of rates. If rates of the Wright demand form are contemplated the information must be worked up in the form shown by Fig. 4. Having obtained information in these forms it will be seen that a given rate may be applied in a very few minutes, with a result that the Commission is at liberty to alter certain phases of the rate as frequently as desired, without entailing a large amount of work in the computations of changes of revenues which are involved. In a particular case which I have in mind fully 60 rates were worked up and applied before a final schedule was determined and the amount of time involved was not a serious consideration.

The revenues thus derived are, of course, revenues for a specific year's consumption, and if the Commission determines that it wishes to take into consideration certain increases or decreases in consumption, these can be readily cared for by methods which are obvious. In this discussion of forms of rates I have not taken up the matter of allocation of property values and operating expense to the different classes of service rendered. Such different classes of service frequently comprise residence service, business lighting service, flat rate lighting service, direct current power service, alternating current power service and municipal street lighting service. These classes of service are very frequently met, and in addition there are, of course, the almost limitless possibilities of limited hour service and seasonal service which may arise. The proper allocation of operating expense and fixed charge items is a large problem and requires further analysis of operating characteristics. In a solution of this problem the engineers of the Illinois Commission, in handling electric rate cases, have usually presented load curves of the electric system obtained from station log sheets of the utility. The methods used for this allocation might well form the subject of an entire evening's discussion, and because of the many issues which are involved I will not attempt such a discussion tonight. In order, however, to give an idea of the nature of the information presented I am reproducing, as Fig. 5, a load curve of an electric plant of which the Commission has made recent investigation. In addition to the allocation of the various classes of electric service, in the case of a jointly operated property there usually arises the matter of

the allocation of property and expense to a water property or a street railway or heating property.

I have discussed in the foregoing the issues which usually arise and may be expected to arise in every rate investigation. In many cases other issues will arise which are entirely dissimilar. In a recent instance a property was under investigation and the usual study of values and operating expenses was conducted. In making some further investigation of general conditions it was discovered that the consumptions per consumer were materially less than those which had been found in other instances, and we came to the con-

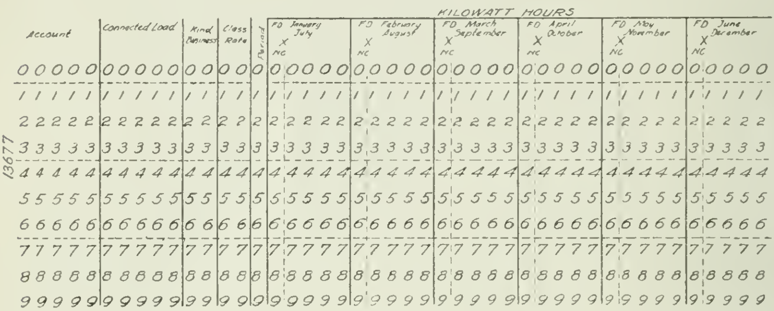

Fig. 6

clusion that the consumers' meters were registering in error. An examination developed that these meters, which were of the direct current commutator type, had been in service for many years without inspection or adjustment. Matters of this nature are certainly of vital importance in a rate consideration and it behooves the engineer conducting an investigation to be thoroughly alive to unexpected possibilities of every nature. Studies of distribution efficiencies will often disclose defects in equipment of which the utility is not aware. In another recent investigation our examination disclosed distribution efficiency of approximately 85 per cent. in a community of about 1,200 population. This excited our suspicion and we made a test of the meter under which the utility procured its energy over a transmission line. This test disclosed that the meter was in error. Clearly a matter of this sort should be corrected before the rates are fixed for electric service. I mention these points as indicating the very wide scope of action and investigation which in justice should be conducted in connection with a rate-making proceeding.

Heretofore I have discussed only the features of the work of the engineering staff which are connected with rate-making proceedings. In its actual working out this work constitutes only a minor portion of the engineering work of a large utility commission. With the Illinois Commission a large proportion of the informal complaints are handled through the engineering department which reports its

conclusions to the Commission. All utility rates filed are examined by the engineering staff. The requests for information made by utility consumers and municipalities regarding technical matters are numerous. In a recent instance, two brothers, operating an electric utility in the State, were drawn for service in the National Army. The community was a small one and a discontinuance or impairment of electric service was threatened. The working out of a means for handling the operation of the plant was a problem presented to the engineering staff of the Commission, and at present appears to be in fair way for solution.

The Illinois Law requires that all inter-utility contracts must receive the approval of the Commission. This necessitates the study and analysis of contracts providing for the sale of power. The matter of rural rates and of a study of possible means for connecting up and handling rural business is a problem at present under consideration by the engineering staff of the Commission. The entire work is so diversified that it offers a rather unusual attraction due to its lack of routine.

In this discussion I have presented no figures, advanced no theories and perhaps only barely outlined a few methods. I have touched upon many subjects, any of which offer fruitful opportunity for discussion. I have endeavored to show how diversified and complete an investigation is essential for a study of an individual case and have tried to emphasize the need for a thorough analysis into each phase of each particular case.

In the course of our work, which has covered several years, we early saw the need of collecting data from every source available even though its application to the case immediately in hand was of doubtful import. Such data collected with care and with copious notes as to the conditions which prevail oftentimes prove invaluable in its application to other cases where its need is more apparent, but where the facilities for securing it are lacking. Thus, in securing consumer data, we have endeavored to analyze it so that it would be available for comparison with other conditions which might be encountered. Data regarding connected loads, monthly consumptions, load factors, etc., are invaluable for certain purposes and difficult to obtain if original sources must be consulted. We have a complete installation of Hollerith tabulating and sorting equipment with which to handle this information and which has immeasurably facilitated the tabulations necessary, besides broadening the possible scope of the inquiries. I show in Fig. 6 a reproduction of the familiar type of Hollerith card which we have adapted to our special requirements. It will be noted that upon this card we show a consumer's connected load, his business, the rate upon which he is served and his monthly consumptions. I have prepared data shown in Figures 7 and 8 for two cities from the results which were obtained by these methods in form which I believe may be of interest and service to you, although not in the form most adaptable for our use. Comparisons of this nature are of interest in themselves and

Kind of Business	Average Active Consumers	Average Connected Load Watts	Jan.	Feb.	Mch.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average kw-hrs. per year per consumer.
Residences*	365	749	25	22	17	15	12	10	9	10	11	18	22	23	194
Saloons and Pool Rooms*	23	1128	135	125	92	95	88	112	106	117	92	111	117	130	1318
Restaurants	5	437	130	126	92	111	100	169	155	134	126	124	129	131	1516
Stores	80	1397	117	81	65	70	60	60	58	78	76	97	111	126	999
Dentists	6	342	11	13	10	4	3	6	8	7	6	8	12	11	97
Livery Barns & Feed Stables	8	513	58	51	33	28	21	18	15	24	27	36	43	51	406
Picture Shows	4	4641	568	601	573	563	607	632	520	555	558	551	1002	612	7335
Photograph Galleries	3	1262	29	32	28	27	22	20	29	16	15	22	41	68	348
Lodge Rooms and Halls	12	1163	30	39	31	39	37	28	21	24	23	31	27	31	362
Printeries	4	1520	143	186	135	111	115	110	84	101	119	157	163	151	1574
Hotels and Rooming Houses	6	1692	259	243	162	158	160	155	112	125	144	176	195	227	2117
Hotels and Saloons Combined	4	3019	381	372	265	306	263	300	230	287	313	352	362	409	3801
Offices and Banks	40	766	49	41	30	32	27	26	27	32	25	29	37	47	402
Schools	3	1663	23	48	22	12	17	19	2	1	4	16	20	36	219
Churches	13	3810	54	46	36	54	37	20	15	12	26	33	37	46	413
Club Rooms, Halls, & Skating Rinks	2	643	21	16	17	9	6	5	5	7	5	26	44	41	201
Blacksmith, Machine Shops & Garages	11	1056	43	17	8	18	22	29	61	41	43	48	53	36	419
Factories	2	2150	180	149	104	90	59	41	31	36	35	35	57	87	901
Plumbers	1	150	5	4	1	1	2	3	14	22	2	3	3	4	64
Miscellaneous**	26	787	80	68	49	52	41	43	42	47	55	60	70	75	681
Average kw-hr. per month of all							33	33	32	26	37	44	53	56	503
consumers	620	1099	57	48	37	38	68	62	60	68	64	80	96	98	
Average All, excluding those							68	62	60	68	64	80	96	98	908
marked thus*	231	1227	99	82	64	68									
Average kw-hr. per month of all							64	66	63	73	71	83	98	102	939
business consumers	255	1330	102	86	62	71									
							319	277	247	280	432	410	501	447	4622
County Jail	1		481	555	475	198	358	122	14	34	247	383	644	541	4085
Public Library	1		538	452	227	525	375	306	207	447	368	485	594	687	5569
City Hall & Fire Department	1		583	569	539	429									

STATEMENT SHOWING COMPARATIVE CONNECTED LOADS AND CONSUMPTION FOR VARIOUS CLASSES OF ELECTRIC CONSUMERS IN A CITY OF 10,000 POPULATION

** Includes Bakeries, Greenhouses, Tailor Shops, Post Office, Barber Shops, R.R. Depots, Laundries, Gymnasiums, and Hallway Lights.

Fig. 7

Kind of business	Average Active Consumers	Average Connected Load-Watts	Jan.	Feb.	Mch.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average kw-hrs. per year per consumer.
			Average Consumption in Kilowat-Hours												
Residences	444	757	21	17	15	15	12	10	10	11	14	18	22	23	187
Saloons	74	897	94	82	75	73	58	63	92	99	99	82	80	101	998
Club Rooms	22	2407	98	89	71	79	71	49	51	47	46	73	104	111	888
Barber Shops	14	399	28	24	19	19	15	15	20	22	23	22	26	31	262
Livery Barns and Feed Stables	6	716	60	56	42	36	28	22	22	27	30	38	56	63	478
Churches	10	1875	31	23	22	23	19	17	11	9	14	22	26	30	247
Tobacco Stores	7	472	45	42	33	32	23	18	18	18	21	30	39	47	365
Schools	13	2425	55	63	45	56	32	27	14	18	21	29	61	43	464
Lunch Rooms	3	530	53	43	34	37	31	33	40	40	40	44	49	62	306
Telephone Offices	2	2315	285	251	219	230	203	174	279	269	233	232	303	302	2980
Confectionaries	9	809	80	64	55	65	63	76	97	101	106	85	87	86	965
Garage and Auto Dealers	5	1062	90	71	61	91	75	72	82	81	99	80	92	94	987
Hospitals	2	8455	220	196	158	183	64	100	102	110	136	184	316	252	2121
Drug Stores	9	1138	112	94	82	87	61	52	59	62	68	86	107	124	994
Miscellaneous Retail Business	221	1660	96	76	61	63	46	41	46	47	56	66	93	115	806
Hotels	2	2317	182	187	157	143	118	110	111	111	125	171	216	208	1839
Average kilowatt all business	399		91	75	62	65	49	43	55	57	63	68	87	104	818
Average kilowatt less saloons	325		90	74	59	63	47	41	46	47	55	65	89	105	780
Average kilowatt all	843		54	45	37	38	29	27	31	33	37	42	53	61	487

FIGURE 8

STATEMENT SHOWING COMPARATIVE CONNECTED LOADS AND CONSUMPTIONS FOR VARIOUS CLASSES OF ELECTRIC CONSUMERS IN A CITY OF 25.000 POPULATION

invaluable as a means of suggestion for discovering conditions which would otherwise not be unearthed. They have also frequently proved of value as a basis for estimate in cases where data as to consumptions were not available.

One hears so much discussion of valuations, rates of return, going value and kindred matters that I felt it would be of interest to spend an evening going over the other matters which too often appear in the background, if at all, and which are nevertheless important in every rate-making issue.

DISCUSSION

A. C. King: With regard to the description Mr. Peck gave of the methods in valuing the property. That is, the three bases on which they make the valuation,—the Original Cost, Reproductive Cost, and Normal Reproductive Cost. This method, I think, in fact, I know, it is somewhat new; it is much newer than the old methods originally used, which were chiefly reproduction cost, and, personally, I have had but little occasion to use any but the reproductive method, although that method generally has been and is, in most cases, modified and perhaps nearly approaches a normal reproduction basis.

Another point which Mr. Peck brought out which I think is very apropos, is the use, or rather the method used, in determining the depreciation in property. It has been largely the custom in the past to refer to tables. This probably is because it is about the easiest method, and if an engineer uses that method and is cross-questioned on the stand, he can refer to Foy or Kent or the Wisconsin Commission or some other Commission who has a table prepared which they generally used, and he can often get away with it, but if he brings in a theory of his own, especially if it is not based on any mathematical theory which he may involve for the case at hand, it is a little difficult for him to sustain his position.

But nevertheless I think that that particular feature is a very important one and one which will receive no doubt more attention in the future than it has in the past.

Then the third point, an item of particular interest which Mr. Peck brought out, is the one where the engineer, you might say, encroaches on the field of the accountant. The field of the accountant really, however, is merely to prepare the figures from the utilities' record. As a rule accountants are not familiar with public utility operations, and about the best they can do is to certify as to the correctness of the record. It is a very important matter, however, with the income and expense statements and they should be carefully gone over and compared each year with the others to see that normal figures are arrived at when used in making up the final income of the utility from the rate-making standpoint.

This is a little better illustrated, perhaps, by a concrete example. A certain utility may charge a portion of the construction account

in their operating expense for a certain year, possibly with the idea of concealing part of the net income. If this is allowed to pass and the rate based on such a net income, it would result in the consumer paying annually to the extent of this particular amount, whereas if the charge was made to the capital account where it belongs, they would pay only the seven or eight per cent rate of return plus the amount allowed for the accruing depreciation. In other words, the annual charge should then perhaps be only ten per cent of the total rather than the whole amount. This is a very important item and I think one that is well within the realm of the engineer, because he is the man who knows what constitutes the proper charges for operation rather than the accountant.

E. J. Fowler, M. W. S. E.: Mr. Peck brought out a good many very practical and businesslike points in connection with the methods for rate determination. The one that appeals to me the most, perhaps, is the one regarding valuation. Up until recently I know whatever the regular body considered it necessary to make an inventory of they made that inventory of every small piece of equipment and apparatus, and they spent a large amount of time and money in so doing. Mr. Peck's suggestion along this line seemed to me much more practical and much more efficient, and I am quite certain will arrive at the correct results as closely, if not more closely, than the earlier methods.

I wondered how Mr. Peck took care of the two sets a month?

Mr. Peck: If you noticed, Mr. Fowler, right to the left of that series of columns was a single column. The punching of that column determines whether the upper row of months is used or the lower row. If one is punched it indicates the first half of the year is used and if the other is punched it means the second half is used.

Mr. Fowler: The statistical methods appeal to me as being very practical and giving just the information that would be of greatest value in any rate study.

If I may be excused for getting away from the question of rate determination,—in the past it applied principally to retail rates. The Hopkinson method has been applied more to wholesale rates. The difficulty that a great many companies have experienced in these two rates—and rate experts have had the same difficulty—is that customers, a great many of them, have approached the point where they are too large to be considered a retail customer and too small for a wholesale customer. Now I have worked recently on a rate schedule for a company outside the state, which has not been adopted, but nevertheless I have presented the idea. That is a method of getting around the difficulty that comes up when the customer reaches that dividing line between the retail and the wholesale customer.

In retail the rate is usually made up of a primary or full rate, we will say, for example, of 10 cents per kilowatt hour,—10 cents for the first certain number of hours' use of the connected account, and a secondary rate for the excess over the primary, we will say

for example, 5 cents per kilowatt hour. The Hopkinson rate is usually made up of charge per maximum kilowatt, a primary charge, we will say, of $24 per kilowatt per year, or $2 per kilowatt per month, with a secondary rate perhaps of $20 or $18 per kilowatt year. And then along with that a secondary rate beginning with so much per kilowatt hour for the first 2,000 kilowatt hours and a secondary rate for the next succeeding kilowatt hours, running off to four, five or six steps. The proposed rate that has been considered simply converts this Hopkinson rate into so much per kilowatt hour for the first 200 kilowatt hours, so much per kilowatt hour for the first hour's use. This $24 per kilowatt is the same as $2 per month. Take a ten kilowatt for example. That is a $20 primary charge,—a ten kilowatt customer at 30 hours per month would be 300 kilowatt hours at ten cents, which would be $30, so that the $24 rate can just as well be expressed as so much per kilowatt hour, if we make allowance for a certain number of kilowatt hours added to the primary charge.

Now this rate retains the advantage that a large number of small consumers still have simply the ten and five rate expressed in two steps, 10 cents for the first 30 hours' use and five cents for the excess. If they are larger than a certain size their connected load is above a certain amount or the meter installation above a certain capacity, we simply add the additional steps to the primary rate and to the secondary rate. For instance, ten cents for the first 300 kilowatt hours and five cents for the excess over 300 of the first hour's use per day, and then for the secondary charge four cents per kilowatt hour for the first 500, and then two and one-half cents, and so on down using whatever rate steps you wish to select.

W. A. Shaw, M. W. S. E.: I was wondering what the parties here assembled would think of the Commission if they were to undertake to do all this, that is, all the details that he described in the work that he has imposed upon the engineering department. It appeared to me, as a listener, there wasn't much left for the Commission to decide after the engineering department had laid before the commission its details of the results of its investigation made from the engineering side. But this only gives you a bird's-eye view of the things that the Commission have to consider outside of the facts laid forth by the engineering department in the consideration of the rate question. There are many other facts that have to be considered by the Commission, and also we have the legal aspect of the question to consider. The Commission from its inception up has tried to profit by its mistakes and by the suggestions that have been made by others and by those appearing before it, and especially experts in testifying in the rate proceedings.

It has been my privilege to hear the testimony of many of our leading experts in the West and in Chicago and vicinity, and I am frank to say to you gentlemen that some of the policies that have been adopted by the Commission, as described by Mr. Peck in his paper here tonight, were suggestions that came to the Commission

from experts testifying before it. For instance, the policy that has been adopted by the Commission in such cases as the Engineering Department, when it is testifying before the Commission in laying before it valuations made upon the theory of original cost as described by Mr. Peck, the cost of reproduction of new, and the normal cost. The Commission, in considering these various theories, expect the Engineering Department to be consistent in each theory, that is, as to the original cost that shall be followed to its logical conclusions, that is, not bringing in part that might be original, part that might be technical present production, and part that might be normal reproduction cost. The same is also true of the other two methods.

The courts have seemed to indicate that all of this character of testimony at least is competent to be considered by a regulatory body. In coming to a decision the Commission has never yet indicated as to which theory they gave the greater weight in coming to its conclusion, and frankly, gentlemen, I don't know that it ever will indicate to the public as to which theory it gives the greater weight.

The courts have indicated that all these things should be considered in the finding of values, as we so call it—and it has appeared to me in many instances that the term "value," as used in fixing the rate, it somewhat of a misnomer. It appeared to me to be more appropriate to use the term, "that amount that is fair between the utility and the corporation or the public." But, as I stated before, the courts have indicated that all these lines of evidence should be taken into consideration when the Commission makes up its mind as to that amount, whether you call it "amount" or whether you call it "value."

In connection with the work I am constrained to read to you a quotation or an extract from a memoranda prepared by the Director of Valuation of the Interstate Commerce Commission. My friend Fowler has brought up the question along this line of the Railway Commissions of Various States. They have what they call the National Association of Railway Commissioners. They meet in convention annually, usually in Washington. In this convention in California in the fall of 1915 the convention saw fit by resolution to have constituted what is known as a Valuation Committee, consisting of seven members. This committee to be authorized to employ a representative to be in Washington on the ground at all times, with the title of Solicitor. It was my privilege to be one of the members of this Valuation Committee, since which time I have been made its Chairman. The Committee employed as its solicitor Mr. Clyde B. Hutcheson, who was at that time president of the R. U. Commission, and since which time he has been made a member of the Interstate Commerce Commission. The Committee of course feels somewhat proud of the selection it made, as its judgment has been vindicated.

During the time that I have been a member I have appeared at Washington on different occasions, have taken part in the discussion, and have listened to discussions, have endeavored to read the briefs and the articles as presented through the Commission, and in

the last briefs filed, which were in the fall, or about three months ago, Director Prouty, who was a past member of the Interstate Commerce Commission, and who resigned as a commissioner, prepared and filed what he called a Memoranda, which I believe is worthy of serious consideration of all good students of regulation, and no doubt a copy could be obtained by addressing him at Washington.

The part that appealed to me was what he stated on the first page, which has to do with, you might say, the legal part of valuation, and what made it appeal to me all the more was the fact that Judge Prouty in time past was a lawyer and was afterwards a judge, I think from Vermont, following with some 10 or 15 years' experience as a member of the Interstate Commerce Commission, in which he has made a particular study of the principles applied in valuation.

The part that appeals to me is that he is getting away from the legal side of it and looking at it from the practical side.

Mr. Fowler spoke of one point that has impressed me, and that is, as I have considered the valuations and the inventories that have been placed before me, the large amount of detail work in making inventories and valuations. I refer more particularly to the small items. There have been inventories submitted to my Commission in which they will list down as low as one-half inch, or perhaps a quarter-inch nipple. I have seen pages of small items which when added up probably wouldn't make more than four or five dollars. In other words, it probably cost more to send someone out to list the property than the material itself was worth.

It has seemed to me that as a practical proposition on many of the smaller items,—you take, for instance, the things I have been speaking of, a man should be able to go into the stock room and by his knowledge of such things estimate sufficiently accurate for the purposes the value of the particular items that were in this stock room.

I remember when I first came to Chicago in my earlier experience I had to do a lot of cross-section work in reference to the streets. I was working in a private office, and I would have to take a man with me and go out. I would put a map in my pocket and pace the distance from the block corners and use my judgment in taking one level across the street. Now at the time I was doing that work, in my leisure time I would check myself up and go into all the details of the cross-section, and I found in checking myself that I was within three or four per cent. accuracy. I am frank to admit, however, that I couldn't do it now, but I simply use this to illustrate my point in this way.

Of course, it is important in the large, main items that they be handled scientifically and carefully and that the details be gone into.

Mr. King: Somehow or other we don't seem to be able to get entirely away from the old matter of valuation. We surely are fortunate, however, after having heard from Mr. Shaw, as I think

we all recognize that he is one of our most eminent authorities on this subject in the country, in having with us Mr. J. T. Ray, and I would like to hear from him.

J. G. Wray: First I want to compliment Mr. Peck for his very interesting and instructive paper. I have just one point to make and it hasn't directly to do with valuation. Heretofore the practice has been before determining a rate schedule to determine the amount of revenue that is to be had at a given time, the gross revenue. That, of course, would depend on the valuation at a given time and the rate of return. Now Mr. Peck has pointed out the digression from past practices. The practice in the past has been very largely to use an average price. I am heartily in accord with Mr. Peck's ideas in this matter.

Another digression involves a normal cost of the property. That involves not the reproduction cost of the property as we find it devoted to the public use, but an estimate, tempered by engineering judgment, as I understand it, of the property that should be devoted to the public use.

Then, we have still another digression from past practices. Mr. Peck has pointed out that the life table has been used, and perhaps misused, in determining the present value of the property and the amount of depreciation that has accrued.

Another very common method has been to inspect the property and to determine its present condition and the relation of, shall I say, units of work, which the item of the plant is capable of getting? But Mr. Peck says that the theory now is to consider the property in relation to its surroundings and present and prospective use and thus determine its remaining value.

Now these three digressions from past practices suggest a further digression. Usually the rate schedule which will be prepared is not a schedule to apply now or for past years, but for a period in the future, and on this I want to ask two or three questions. Is such a period determined? If so, are estimates of expenses for that period made? If estimates of expenses are made, does the engineer presume to estimate the plant additions and the future value of the property devoted to the public for that period? That, of course, would take into account not only the growth of the plant but the increase or decrease in the cost of materials and labor.

I just present this thought and if Mr. Peck can answer the questions, very well.

Mr. Peck: I can answer Mr. Wray's question as far as my own practice is concerned. In estimating expenses I have usually tried to do it by taking the year, which was six months either side of the date of the valuation and estimating revenues have attempted to use consumers' statistics for a yearly period which is six months either side of the valuation. I feel, as I have tried to bring out in my discussion of the matter, that the function of an engineer appearing before the Commission is to put up engineering opinion, which is

based upon facts, but not to digress from that into the realm of future possibilities, except to lay before the Commission the facts which will naturally determine the future operations of the property. That is, if there is a large amount of business which may be secured in the future, I believe that fact should be presented to the Commission as a fact. If the community is a dead one, I believe that should be presented to the Commission as a fact. But in the estimation of revenue and operating expenses it has always been my policy in presenting evidence before the Commission to limit myself to the year, to six months either side of the date of valuation, with the idea that that year's operating expenses and that year's revenues were determined as nearly as could be gauged by the plant which was valued in the middle of the period.

R. F. Schuchardt, M. W. S. E.: I was very greatly interested in Mr. Peck's paper. I don't want to take the time to say very much, but there is one thought I would like to express and that is, that this paper of Mr. Peck's, as well as Mr. Norton's paper some months ago, emphasized very strongly what is meant by an expert,—the fact that real brains are needed, that special training and intelligence is required to regulate property, is brought out very clearly in these papers. I am very glad it has been brought out as to how strongly the Commission leans on engineering data.

It is interesting to note that at this time there is a conference in the city, discussing a subject which is somewhat allied to this tonight in a little different way,—a conference on public ownership, and that a paper this evening,—perhaps being discussed this very minute, is by a mayor of a neighboring city on the subject of the "Failure of a Regulation." Now I am very sure that where a regulation has fallen down, politics has gotten in ahead of everything else, and where politics rather than sound engineering is the determining bid in the work done.

K. B. Miller, M. W. S. E.: I think the hour is so late, and there is so much I would like to say, that I had better not start. I do want to express appreciation for the paper, however, and particularly I would like to say I am in thorough agreement with Mr. Shaw that a great deal of money has been wasted, and is being wasted, in the matter of too great detail where common sense applied would answer. However, there is a good deal of excuse I think Mr. Shaw will agree, sometimes at least, for the prepartaion of a great lot of detail, when you remember the harrowing cross-examination that an expert is likely to get from an opposing counsel, and the fact that at least many people have been afraid to go before such cross-examinations and not be able to swear they had seen the nail on the third cross-arm of the third pin on the third pole, and because they hadn't seen it that the whole thing would be wiped aside as worthless.

Now there is a middle ground. And yet it don't seem to me as if we should take the middle ground. We should lean towards the common sense determination of plant costs as measures of value

in so far as it applies to determination of value, and we should avoid more and more this fine tooth comb business which leads more to errors than it does toward accuracy.

Mr. King: I want to say just a word. I agree with him thoroughly in the matter and I believe that the difficulty has been due to the legal side of the question rather than the engineering side. I think if the matter was left to engineers that they wouldn't have to inventory every nail and screw in a power plant, and in fact I think that probably Mr. Shaw will agree with me that a great deal of the time, effort and energy spent on regulation work which has been unnecessarily spent, I might say, has been due to the legal end of the situation, rather than to the common sense or the engineering side of it.

In that connection I might say that in one case in which I was concerned the inventory in the power plant required something over five hundred typewritten legal cap pages. You can imagine how much of a job it was to inventory that and put a value on it.

Now there is one other gentleman here whom I think can give some valuable thoughts, and I would like to call on Mr. Prior.

J. H. Prior, M. W. S. E.: Mr. Peck referred to the fact that in certain places the man who attended the plant had to make out the bills. He informs us that the books of certain plants would be kept by a man who also had household responsibilities, and alongside of an item of a pole would be a gingham dress for the little girl. It shows the difficulty of imposing a particular form from which particular information could be drawn.

Mr. Peck, I would like to ask you on this system of yours if the cards were exhibits in your reports, and were you ever asked as to whether that was a proven fact, or was the source of your information questioned as having come from a machine?

Mr. Peck: No, sir.

THE RATIONAL METHOD OF DETERMINING TYPES OF ROADS FOR A COUNTY BOND ISSUE

By William Walter Marr.*
(Deceased.)

Presented December 18, 1916.

In 1913 the Tice Road Law providing for state aid in the construction of county highways in Illinois was passed. A feature of this law provided that the State Highway Commission should select the type of road to be built, and the county and state should each pay half the cost. Although in the first instance there was some other appropriations made from the general funds, the automobile license fund has been the principal source of state revenue for building these state aid roads.

The law also provides for maintenance, and is unique in this feature, the writer believes, as compared with municipal laws. Such provision really makes the difference between building roads as now built by the state, and as built by cities and villages.

With maintenance provided for, on a state road, the problem takes on more of the commercial aspect, that is, such things as the esthetic features, the noise, and other contributing factors entering into the selection of type for a city pavement are absent in the country road proposition, and the state is concerned mainly with getting an economic type which will give service to the people who wish to use those roads. The aim is to establish what may be designated as a *rate of service*.

This rate of service is directly comparable with rates in any public utility, such as for electric lighting, water supply, gas, steam and electric railroads, the telephone, etc. It is believed that the establishment of this rate is the most important thing in the scientific selection of a proper wearing surface. And it is a feature that is generally neglected. Types are advocated almost without regard to what the actual cost of service will be.

As stated, when the law was passed in 1913, the State Highway Commission had the power to select the type, but the county had the right to designate where the improvement should be made. The State Highway Commission was thus confronted with the maintaining of the state aid roads that were built, though it had nothing to say as to their location. If the county designated a highway, for instance, for an improvement, and there was heavy traffic on this road, the cost of maintenance might be very heavy. And so the stated adopted a "Safety First" policy. They determined that they would use brick and concrete roads, and maintain them for all time, in accordance with the law. This was primarily on account

*Chief State Highway Engineer, Illinois.

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of this maintenance feature. They did not, at that time, understand the problem facing them well enough to proportion types with respect to the amount of traffic which would come upon the road, and since only concrete and brick surfaces were selected, this led to a great deal of discontent. The counties wanted home rule. They wanted to select the type themselves. Having little knowledge of engineering, they yet thought rightly, that in some places a gravel road should be built, and they did not care to get a mile of concrete road and then jump off in the mud. Their ideas were confused, but in many instances sound. Will county (Joliet), for instance, started out with a ten-foot roadway, and changed to a fifteen-foot road after the contract was half completed. At the end of that contract they started in and spent their reallotment on an eighteen-foot road. And then they dropped back again to a ten-foot road for part of the distance, and after that was done they wanted to come up to eighteen again, all the time working away from the town, without any regard for the requirements of the case or the propriety, cost or anything else.

In 1915 the legislature amended this law so that the counties were given the right to determine the type as well as the location of the road. The first result of this amendment was a big movement by nearly all the counties to build earth roads without regard to the amount of traffic. A short experience with these roads, however, changed the minds of the various county authorities, and they asked for new surveys and different types. Various material interests at this time entered into the problem, each promoted by its advocates, and the result was increased confusion. However, as a result of all the agitation and confusion and thought on the subject there developed a general demand for a county bond issue for building hard roads as opposed to the local township bond issue or appropriation method.

Under the law as amended in 1915, the county is enabled to anticipate by a bond issue the allotments to be made yearly by the state for road building purposes and thus to reimburse the county by applying the state allotment toward the payment of the bond to the extent of half of the cost of the system. It was shown that these state aid roads could be built at a cost of five to eight cents per acre, spread over a period of twenty years, or about a dollar and a half or two dollars an acre total cost including interest.

The movement that was started when the above facts became known was a little short of marvelous. About thirty counties started campaigns for good roads. The County Boards, however, did not appreciate that people must be educated to vote bonds for road building, and while the Boards themselves had received their education from the State Highway Department the voters generally had not so been educated. The result was that these elections were pressed too rapidly and most of the counties that did vote failed to approve the bond issue. The reason was plain; for in-

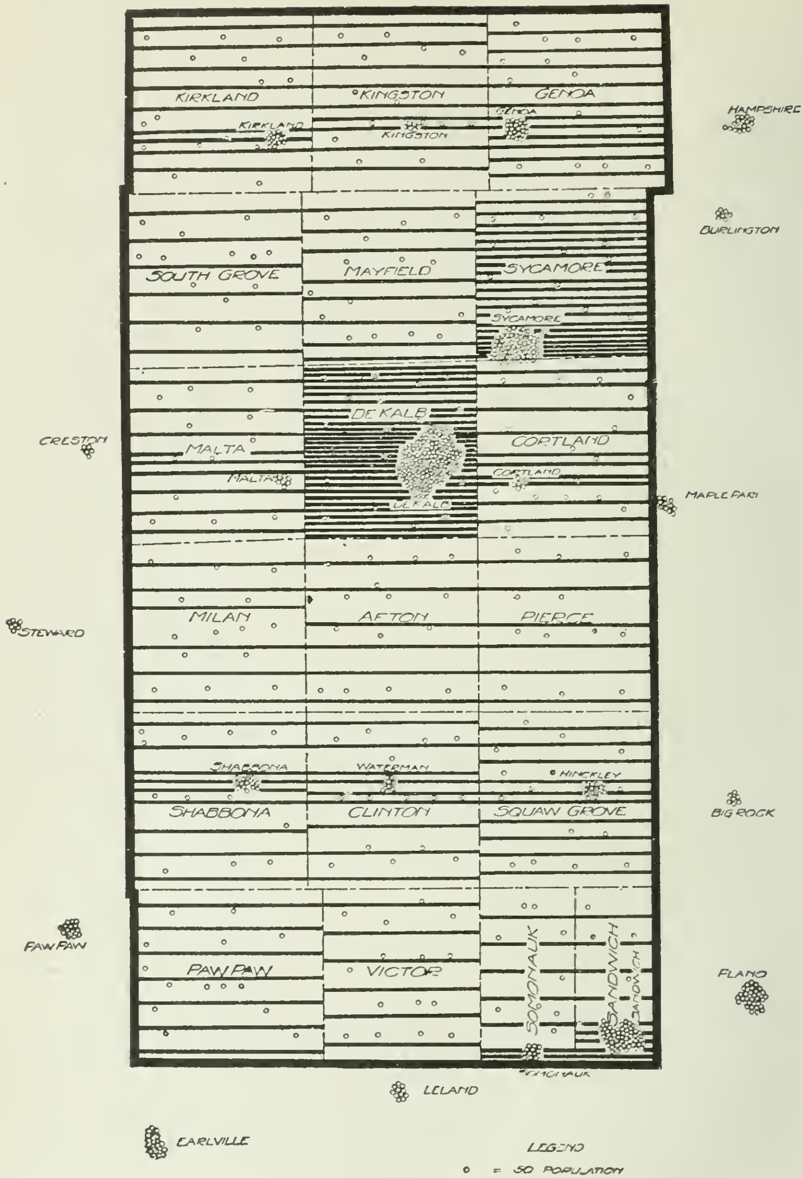

KIRKLAND
KINGSTON
GENOA
HAMPSHIRE
BURLINGTON
SOUTH GROVE
MAYFIELD
SYCAMORE
DE KALB
CORTLAND
CRESTON
MALTA
MAPLE PARK
MILAN
AFTON
PIERCE
STEWARD
SHABBONA
WATERMAN
HINCKLEY
CLINTON
SQUAW GROVE
BIG ROCK
PAW PAW
VICTOR
SOMONAUK
SANDWICH
PLANO
LELAND
EARLVILLE
LEGEND
o = 50 POPULATION
= $100000 ASSESSED VALUATION

Fig. 1

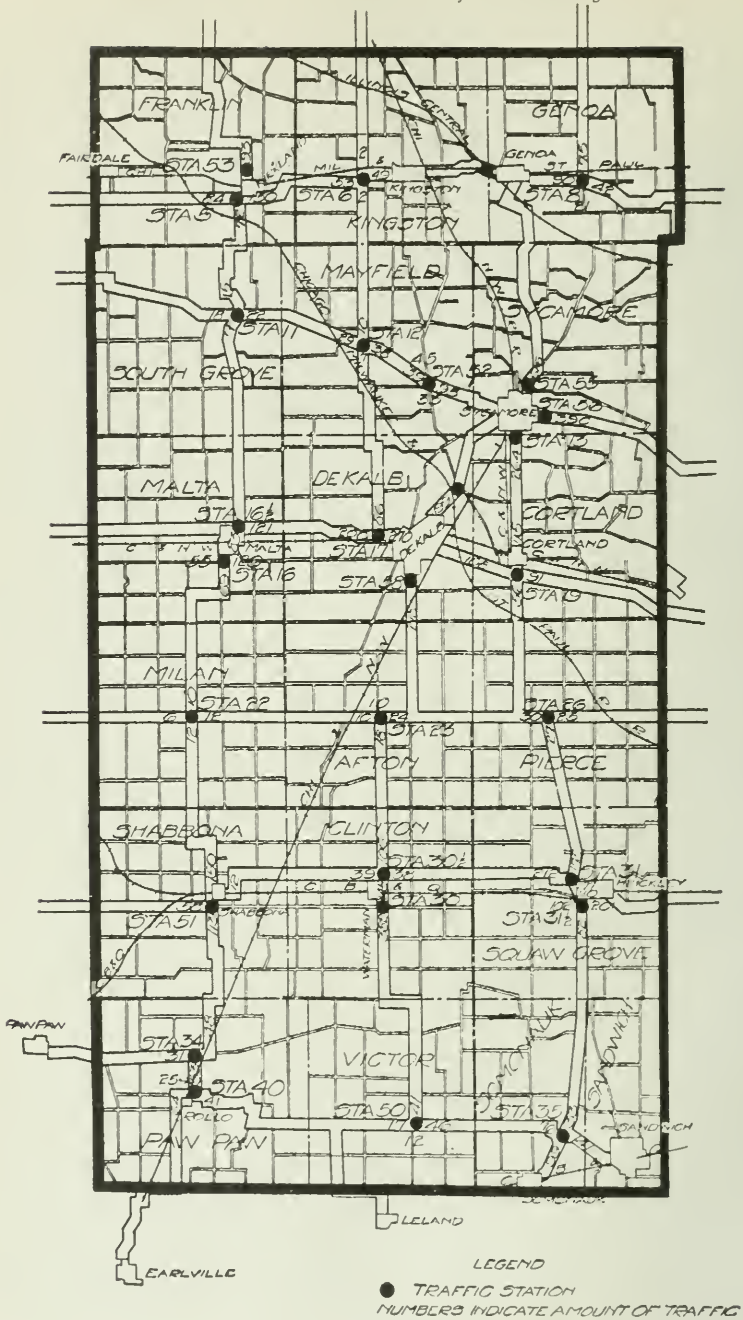
stance, in St. Clair County and in Jackson County, both of which voted in 1916. The bond issue itself carried but the tax levy for paying off the bonds lost. Under the Illinois law it was necessary to have both propositions on the ballot, the first to issue the bonds, and the second to levy a tax to pay those bonds. As the voters did not understand, and as it was not very thoroughly and carefully explained to them, very naturally they refused to vote for what seemed to them a double taxation.

However, it was decided in a good many counties to issue bonds. And the problem of the State Highway Department was to furnish a simple, sane method so that they could themselves work out a reasonably rational system of hard roads, the types to be in proportion to the requirements of the traffic. The following explanation will show how this question was attacked. And in order that it may be better understood it will be stated that the cost of service referred to previously, means, broadly, the first cost plus the interest cost, and plus the maintenance cost—three different items added together and divided by the number of vehicles, or the ton mile, or some similar unit, the result being a rate. This is the cost of service referred to.

Fig. 1 shows a plat of DeKalb County. The horizontal lines across the townships each represent a hundred thousand dollars in valuation. The small circles indicate the population. The City of DeKalb, with the concentration of population and also of valuation, is plainly indicated. These plats are guides. They are graphical illustrations showing where population and wealth are concentrated, and hence the heavy lines of traffic would of necessity follow along such lines. It can be seen the line of traffic through a less densely populated part of the county, as for instance a tier of townships which has no cities and villages, could not be anything compared with that of the city of DeKalb. And yet the people in such a township, if it is intended to vote bonds, will immediately demand just as good a road as any other township.

With the main line of traffic thus indicated, one of which is the Lincoln Highway, for instance, it is possible to visualize in some way where the various lines are going to be, and in this way determine which should have the heaviest type of road that is to be adopted.

The next guide is a traffic count. For this purpose a map (Fig. 2) is shown with the state aid roads indicated. The roads are the state aid system previously designated by the County Board and represents twenty per cent of the mileage of the county. These have been designed for improvement, and a bond issue would cover practically the whole mileage. The traffic is counted on each one of those roads. And the idea of a traffic census is not to predetermine the amount of traffic for the future, any time in ten years or five years or even one year. The purpose is solely to get at the *relative* importance of roads, the *relative* amount of traffic on those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MALTA
DEKALB
CORTLAND
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MILAN
STA 22
STA 23
AFTON
PIERCE
SHABBONA
CLINTON
STA 30½
STA 30
STA 31
STA 31½
STA 51
SQUAW GROVE
PAW PAW
STA 34
STA 40
VICTOR
STA 50
STA 35
ROLLO
SANDWICH
LELAND
EARLVILLE
LEGEND
TRAFFIC STATION
NUMBERS INDICATE AMOUNT OF TRAFFIC

Fig. 2

roads regardless of the actual amount. At first sight it might be said that the traffic on any one road might not be the same tomorrow or on a Sunday as it is on a week day, or it might not be the same in the spring or the fall or the summer or the winter, and that if the count is not taken over an extended period it is useless. If it is taken over an extended period it would be physically impossible to digest it. There would be such a volume of stuff that it would never even be examined. The purpose of this count is to furnish a guide, one of three or four guides to determine the most economical type of road.

Examination will show that there were six vehicles which used one road on that day. This is a one-day count, but was taken on a fairly average day. But that is all—only one day. This road carried six vehicles. Another road carried six hundred and sixteen. The significant part is that one road was carrying one hundred times as much as the other. And what does it matter where the count varies a little? The relative intensity on individual roads remains approximately constant throughout the system. There are a hundred different intensities, but not enough types to proportion the roads that closely. The purpose is solely to get the relation or relative importance of the roads. There is one that carried two vehicles and one that carried two hundred vehicles—one hundred times as much, again.

After the above information is secured the next step is to lay out a rational system of roads, varying in type from the surfaced earth road to that having the heaviest type of construction. This is laid out as a suggestion or basis on which to work, and does not carry with it anything in the shape of a recommendation from the State Highway Department. Its real purpose is to persuade people, or to excite the interest of the local people in solving their own problems. The State Highway Department recognizes the fact that the law makes this a local issue, insofar as the County Boards are empowered to determine the type and to determine these locations. If the Department is able to stimulate their interest and make them think and work out their own problems then it has done the best it can do for them.

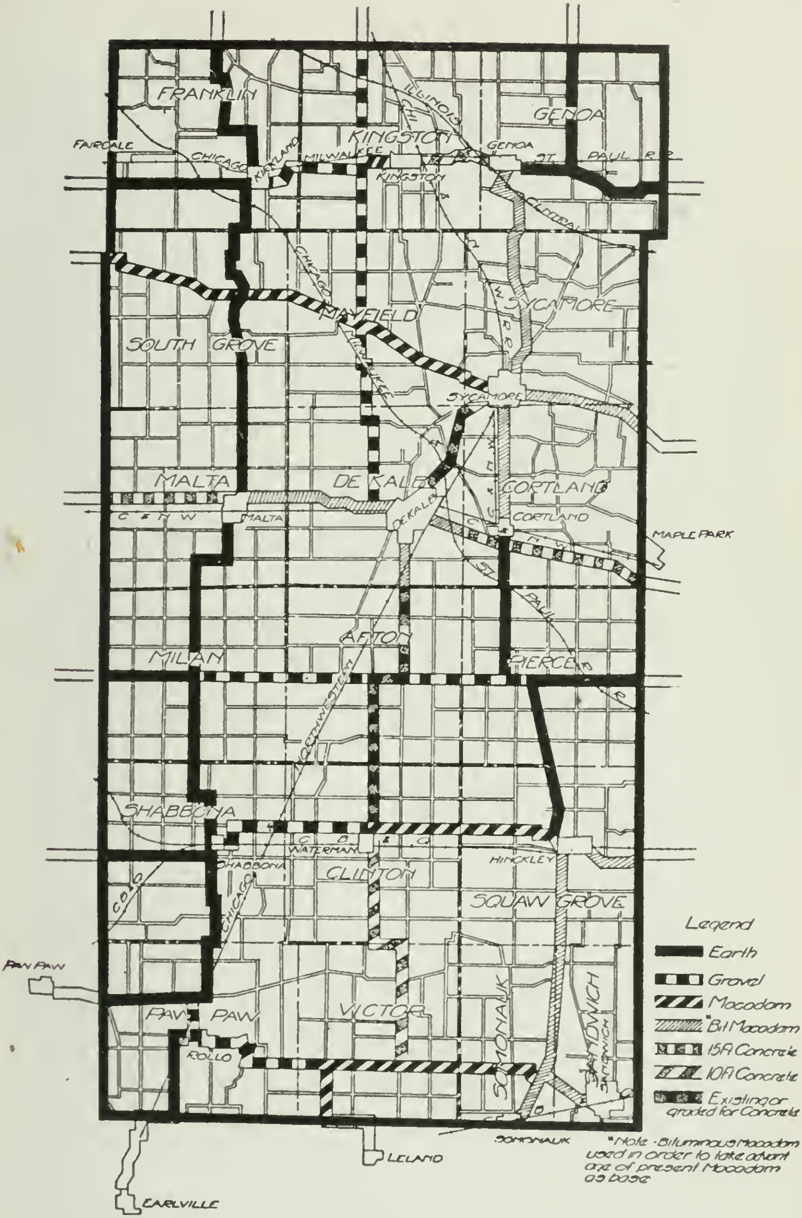
A typical instance will show how this method worked out. A plat of DeKalb County showing the proposed system was prepared. This plat was then handed to a member of the Commission who was a resident of DeKalb County and thoroughly familiar with every foot of existing highway in the county, with all its populations, statistics, etc. A very cursory examination by the Commissioner led him to disagree radically with certain portions of the system as laid out. Up to this time he had not been particularly interested in the proposed method of establishing a balanced system of highways, but the instant his own county was brought into question he developed a very lively interest in the method, and at his own request several plats were furnished him and he began to design a system suitable to the county, himself.

His first work was to mark on the map roads that were already improved to some extent, and his second, to indicate that part of the state aid road system already improved, or for which many had been provided. This was his working basis and was the information which was not available to the speaker at the time the first system was laid out. In the meantime he had been furnished with a table showing the approximate unit cost per mile of road for various types of wearing surface, and with the aid of this table and the maps previously mentioned, which he had become thoroughly interested in, he designed a logical system of roads for that county. An estimate of cost was then made of it as laid out and found to be about $740,000. It is evident that this system was then a reasonably well designed and logical system—that it connected the cities and villages of the county, and that it was rationally arrived at. The commissioner, however, was not satisfied by that time. DeKalb County could raise $900,000. Hence the problem was to use that additional money economically. And therefore, additions of bituminous surface to forty miles of gravel and macadam were made, so that in doing this it takes up the $900,000 the county was able to raise by a bond issue, and the system covers most of the roads of the county.

But even then the Commissioner was not satisfied. When a man gets started on a problem of that sort he is bound to develop new ideas, and will develop not only what is best in his county but will consider adjoining counties. This was so in this case. The Commissioner went on and connected up his design to the other counties, in the outlying districts, following along the general lines of that population and valuation chart. And he laid out earth roads properly graded, which would give the service commensurate with the service throughout the entire system, by reason of the smaller number of people who would be using those roads. It was found this would increase the total cost $100,000, or a total of $1,000,000 for the completed system of two hundred miles, when the county could only be bonded for $900,000.

It was then necessary to consider how the additional $100,000 could be raised. The law provides that the bonds may be divided into annual series of from 10 to 20—not less than 10 nor more than 20. After some thought the following scheme was evolved: Bonds for $900,000 to be issued in a fifteen-year series, payment of the principal to start at the end of five years, and thus the value of the money would be received during the construction period. In the meantime the county to receive its regular allotment of state aid, and instead of applying that to the payment of bonds or interest, the money to be saved and put into the road system, thus enabling the county to spend $1,000,000 on its system and cover the whole 200 miles.

This scheme worked out very nicely in DeKalb County, and was taken up immediately in other counties. The principal duty of the State Highway Department then became to give a sort of a course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ST. PAUL R.R.
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CENTRAL
CHICAGO
MAYFIELD
SYCAMORE
SOUTH GROVE
MILWAUKEE
SYCAMORE
MALTA
DE KALB
CORTLAND
C & N W
MALTA
DEKALB
CORTLAND
MAPLE PARK
AFTON
MILAN
PIERCE
NORTHWESTERN
SHABBONA
WATERMAN
SHABBONA
CLINTON
HINCKLEY
SQUAW GROVE
CHICAGO
PAW PAW
PAW PAW
ROLLO
VICTOR
SOMONAUK
SANDWICH
SOMONAUK
LELAND
EARLVILLE
Legend
Earth
Gravel
Macadam
*Bit Macadam
15 Ft Concrete
10 Ft Concrete
Existing or graded for Concrete
*Note - Bituminous Macadam used in order to take advant age of present Macadam as base

Figure 3

of instruction to the various counties that were contemplating bond issues. And for each county, similar maps and combinations were made up.

Fig. 3 shows a sort of balanced system, or rational system of laying out the roads, in order that the cost of service or rate on each road shall be constant throughout the system. That is the real aim. Each member of a County Board is given a map and it is found that such a proceeding is almost sure to make them find fault with it. And that is just exactly what the Highway Department wants them to do, because it is really their problem. No recommendations as to type are made. The County Boards solve that themselves. But the Department tells them what it knows of types and how they have acted under various conditions, under varying amounts of traffic, what they can be expected to carry, what their cost will be, what the maintenance charge will be, etc. In that way it is found that they are more likely to come to the department with their problems and to seek advice than they would otherwise.

One of the prime causes for the present tendency of counties to propose a bond issue for the development of a county road system is the fact that in the few instances of this state, where there has been a county bond issue the work has been done at a materially lower cost than the piecemeal work possible under the State Aid method of doing work—that method consisting of allotment each year of a stated sum to each county and to which the county adds an equal amount. The first result of the State Aid method was the building of piecemeal roads. The natural result being that the overhead expense for inspection, etc., was very large, many of the jobs being small and therefore the unit cost very high, and when bids were received in this manner the County Commissioners were reluctant to let the work at prices materially higher than they understood it was being done some place else. When it is explained to them that the reason for the high cost was the scattered work and the small size of each particular job, and that from twenty to twenty-five per cent could probably be saved on a comprehensive county system, the incentive is very strong for them to begin to figure on such a connected system.

The locating of the roads to be improved is another thing that causes a good many troubles. The counties have the right to locate the roads. Under the law, each county must have a Superintendent of Highways. Not many counties had such an official and only when they found out that they would have to have a county superintendent of highways in order to carry on their township business and designate a system of roads in order to get any of the state money, was one appointed. The first decision as to a county system of roads was hurriedly made.

The law also provided that the first map could not be changed for three years. Now, most of the counties want to make some

changes, and there will be another upheavel at the end of the three year period. But because of the study outlined, so many of them having approved the bond issue proposition, they are beginning to realize the importance of locating these roads by some other means than by the pork barrel method. It is impossible to get away from the human nature tendency, for the representative of a district to carry back to that district the most that he can get, regardless of whether it deserves it or not. And any county board member is sure to go in and fight for a concrete road or a brick road in his township, whether there is anybody living there besides himself or not. He wants to get the highest type of road. He figures immediately that his people are just as good as any people and that they are entitled to it. And of course he lobbies for it. To get around that problem, the Highway Commissioners endeavored to get as many on a committee as possible—some six or eight, maybe ten, on a committee from a county board. It is endeavored to get them interested in their problem, and it is assured that they are going to take their little maps home, and that each member will put all the high type road in his own township, and the other fellow will get pretty near what he deserves but the first fellow will get the lion's share. The way it actually works out is that each fellow will want the best for himself, and when he gets back into his committee meeting there are nine votes against him to one for him for his own township. And so by compromise and trading, a reasonably well distributed system throughout the county in proportion to what they actually require is secured.

A plan can only be submitted to the people in this state by action of the county board. A county board cannot be mandamused to submit the proposition to the people, nor can action be forced through petition or in any other way. Some of the most serious mistakes in this campaign have been made by enthusiastic business men.

People go out to determine a type of road—a county board. If they go over in Wayne County Michigan, and the concrete people are fortunate enough to get them there, and nowhere else, they will come back and vote to a man for concrete roads for the whole system from one end of the county to the other, nothing but concrete. And after riding over three or four hundred miles of it, who would not? If they go over to Cuyahoga County, Ohio, and ride over three or four hundred miles of brick pavement, they come back unanimous for brick and say "Why not do this right?" Then if they go over and ride through Indiana on five or six hundred miles of gravel or macadam they say "That is good enough for them, and it is good enough for us. Why should we want to be burning up our money for more expensive construction?"

What the Highway Department attempts to do is to get them to go to Wayne County, and to go to Cuyahoga County, and to go into Indiana, to get them to go over some of the bituminous

construction around Chicago and up in Wisconsin. It is money well spent. It loses the junketing feature then for the county board. They learn something. And if they don't learn anything else than one thing, that a single type cannot economically meet the requirements of a county system of roads, they have done a great deal for their county.

To return to DeKalb County, it is simply idle to contend that any one type could economically meet all requirements. To begin with, two vehicles a day on one road, and six hundred vehicles on another—all sorts of different kinds of traffic. If the cost is $10,000 a mile for pavement, and 1,000 people are using that pavement, the rate of cost is $10 per person. If, on the other hand, there is a gravel road that costs $5,000 for the same traffic, the rate is reduced to one-half. Therefore, the interest cost, the first cost and the maintenance cost must be so balanced that the rate will be least.

Maryland and Pennsylvania have a large mileage of gravel and macadam roads. Most of those roads are good roads. They are in fine condition and some of them have been there a hundred years. It is not claimed that any of the original material is there. But the fact is that they have given perfect service. And the reason for that perfect service is constant maintenance. The patrol system of maintenance is used. The cost on those gravel and macadam roads in that section is around $200 to $500 per mile per annum—$200 per mile perhaps, as an average, and they are carrying traffic now up to four or five or sometimes seven hundred vehicles a day. That means constant maintenance by the patrol system, and a very economical method under a competent engineer whose system is perfected. In addition to the patrol system a gang system is used: an organized and proficient gang of men who make extensive repairs where such a method is more economical. But the point is that the law in Illinois provides for constant maintenance, and the department should give due consideration to the possibility of developing each and every type to its utmost capacity rather than adopting without consideration a higher type where that higher type is not in any way required or needed.

The State is now working on the proposition of Federal aid, together with State aid, and the Legislature will probably pass a bill proposing a bond issue of $60,000,000 to provide a state-wide system of roads. This will be voted on in 1918. Such a bond issue will provide for approximately 4,000 miles of road covering the main arteries of all parts of the state.

DISCUSSION

J. G. Gabelman, M. W. S. E: In laying out these township roads do they take into consideration these connecting lines, if there is any attempt made to connect up with the system?

Mr. Marr: You mean, for instance, Mr. Gabelman, when we have a system like this (Fig. 3) do we consider what is already constructed?

Mr. Gabelman: What I was figuring on, when you are designing that system, whether you have in mind this other system?

Mr. Marr: As a matter of fact we do caution all of these county boards who are rushing into the design of their system, that they are treading on pretty dangerous ground. We know that the chances are a hundred to one in favor of a state bond issue in the near future, and we also know that Federal aid is now ready. There is $220,000 apportioned the first of July, 1917, and $660,000 the first of July, 1918. This legislature will therefore have to appropriate $1,320,000 to meet the Federal aid that will be available during the life of this next coming legislature. That means $2,640,000 that we know will come from the Federal government and state. That is, I don't think we know it exactly because we are up against a pretty serious proposition there in that one of the provisions of the Federal law is that the government cannot pay money directly to a contractor. The Federal law provides that the money of the government shall be met by a like amount from the state. It also provides that the state shall build the roads and make the contracts subject to approval by the government authorities. Now, that follows directly in line with the state aid proposition. That is, the government law and the Illinois state law are almost a parallel, or alike. Now we find out that the government will not pay a contractor. They will pay the state. And we also find out that the state cannot take it. So we are up against it pretty hard there. I don't know what we are going to be able to do about it. This involves a state constitutional question.

It seems that the state treasurer is not authorized—(he can take funds) but he cannot pay them out again except by action of the legislature appropriating certain moneys. Now, if the state treasurer takes this money it goes into the general fund of the state and cannot be removed by the treasurer again until specifically authorized by the legislature. Now, we have tried, of course, to get around that by having some other officer do it, or having the legislature direct the treasurer to do it, but we find out that that is unconstitutional.

How we will get around the thing I do not know. It is too serious a thing, it seems to me, to drop. There is no real solution of it yet, but we are working on it at the present time. It may be that we can get that money in some private bank or something or other of that sort—that is, the state go ahead and pay its share of the work, pay the total cost of the work as it progresses, and the government come in and pay its share in the shape of partial estimates or final estimates after the work is done, and reimburse those who have advanced the money. It is a difficult situation.

Mr. Gabelman: A certain road might be little traveled now, and when connected up with all these counties a heavy traffic might be on it because it would be a short cut from one county to another. Is there any attempt made to systematize the township roads so

that they will fit into one big system, in other words a state highway system?

Mr. Marr: Here is what we do (Fig. 1.) We have shown here the surrounding towns, like for instance this. That is another one of the guides I did not mention. We know the traffic from here up here (indicating) will be greater, and therefore we keep in touch with the activities in this county. We only go a short distance, but we can proportion those things taking into consideration all the various guides that we have. And then supposing we fall down. Supposing we have built a gravel road that should have been a concrete road, what is lost? The cost of the gravel road maintenance is only a couple of hundred to four hundred dollars possibly a year. Supposing that you put in this, with any reasonable amount of traffic, that is all short pieces, or if the maintenance is neglected, when it does go it might amount to reconstruction—it ought to pay you a thousand or ten thousand. There are plenty of gravel roads that are costing two thousand a year because they wait two or three years, and then it is reconstruction. So you lose all of that. But if you get a gravel road, and determine you need a higher type, all you lose is a little of the maintenance, some two or three hundred dollars a mile a year for two or three years. That ought to, under a proper system of accounting in the county itself, and with the aid of the county engineer, show up on the books or the records, and show that it is uneconomical, and then it will be a question of resurfacing or something of that sort. And I think the loss would be comparatively small.

Take DeKalb County, for instance, with two hundred miles of road, if you build that of one type costing $10,000 a mile, you have a $2,000,000 cost to start with. Now, the county's money, or the people's money is worth just as much as the individual's money. There is no getting away from that. If you take four or five per cent, whatever you want to take, it is safe. They can either invest that money and keep it, or they can put it into their roads. So we will assume we have five per cent for all that money. At the end of the twenty year period you have $4,000,000 cost for those roads, neglecting maintenance. If we can go along and design a system like one of these, for $1,000,000, at the end of twenty years you have $2,000,000 cost for that mileage, or half the total cost of the other, a saving of $2,000,000—a saving of twice your original cost in the twenty year period. Those are the things we are looking at, those million dollar items. We do not pay any attention to ten or twenty thousand dollar things. We cannot go into their problems at all. All we can do is advocate a reasonable, rational system. If they go widely wrong on one or two roads, what is the difference, ten or twenty thousand dollars out of a couple of millions, but if they go radically wrong in the first instance and take a uniform type, there is a million or two gone. There is the thing we are trying to avoid.

T. F. Quilty, M. W. S. E.: In connection with the federal ap-

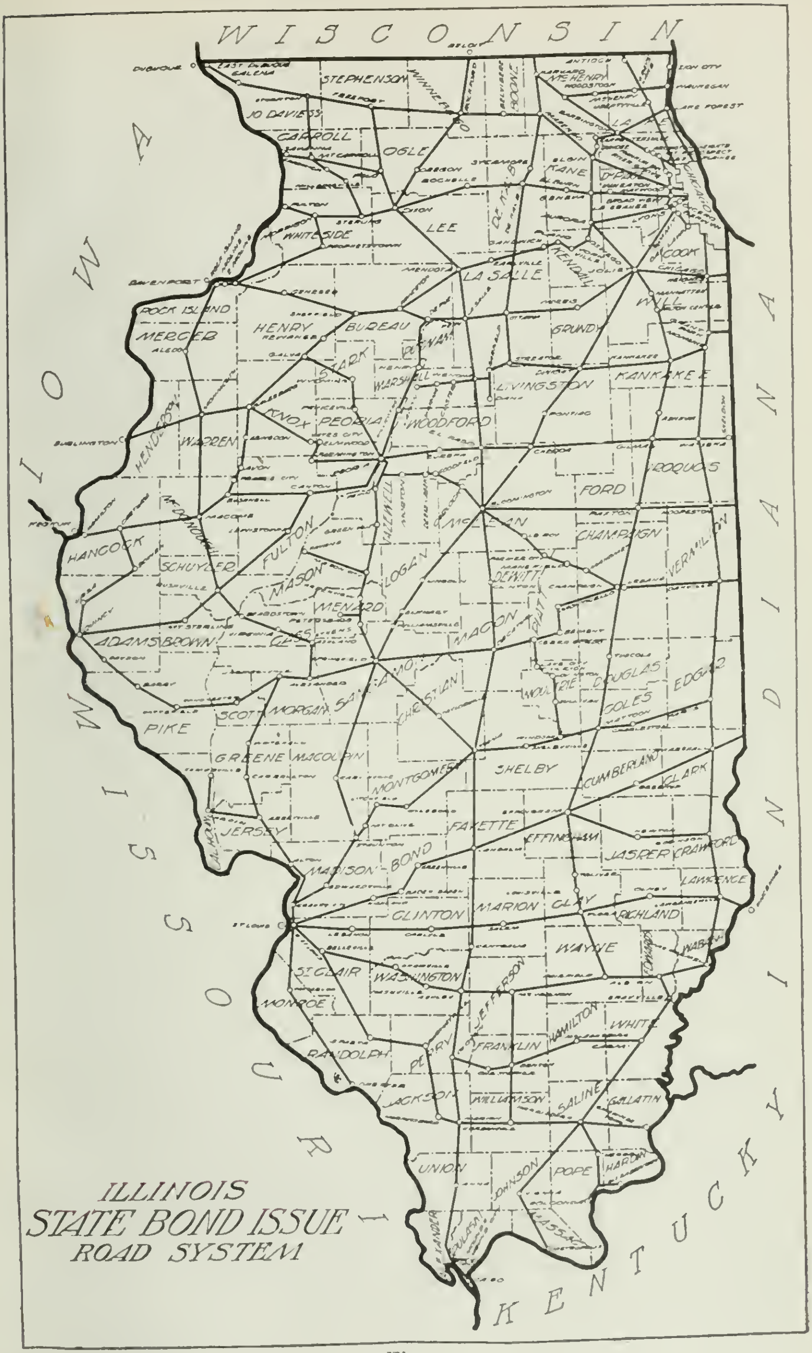

Fig. 1

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propriations, is there any attempt made to locate those roads so as to be of value to the nation as a whole, say for military purposes from one state to another, as from one county to another?

Mr. Marr: I don't mind telling you confidentially what I would like to see done here in Illinois about the federal aid proposition, if you won't tell anybody. I would like to see this road through here (indicating on the map), the Lincoln Highway, and this one down here to St. Louis, and that (indicating) one built, which is a Z system comprising a little over eight hundred miles. That could be built with this federal aid, that is the federal aid that is now appropriated from $75,000,000—we got something over $3,000,000,and we meet it with a like $3,000,000, and we could interest the counties along those lines in putting up an equal amount, giving us approximately $9,000,000, which would build such a system with a suitable type, making a federal system of roads for military purposes, giving us here a cross country road, and an interstate road, and then across there (indicating), which I think would be the biggest thing for the state.

Now, you must see what the legislature will do. The legislature will in all probability be like all legislatures, and will do for their districts as individuals just the same as these counties want to do. We have in the federal law a provision that the money shall be expended under the direction of the State Highway Department. But the legislature must appropriate a like amount; now, whether they will tie strings to it and say that they want to give to each county a pro rata share with the result that you get two cents worth of road in each county, or whether they will do it on one system remains to be seen.

We took the matter up with the Attorney General. We must of course meet the federal allotment. We must get the legislature to do that, and we must do what the legislature says. But the government says that they will not approve a project unless it looks rational and reasonable to them in the first instance. We went especially to the Attorney General on that proposition when this was new, and having our experience here in Illinois with these Illinois counties, and knowing the tendency of a legislature composed of elected representatives, we went to Washington and explained the matter to the government officials and got the Secretary of Agriculture to issue an order directing the state to submit a five year plan in the first instance showing good faith on the part of the state not only to build these roads along some rational plan, but also to maintain them.

Now here is the difficulty that we are up against, if the legislature ignores the Secretary's order, as County Boards did when we tried to show them our requirements, we are up against it from that angle. If, on the other hand, they attempt to build a system from here to here and from here to here (indicating on the map) such as I suggest, connecting the biggest centers of population and serving the greatest number of people then you are up against the

constitutional proposition which prevents special legislature. The state cannot build a local improvement under the Illinois law. That is provided in the constitution. So the legislature could not designate such a thing to be done. We are attempting to get around this by having the legislature appropriate to our State Highway Department in co-operation with the United States Government in some manner an amount of money and that the State Highway Commission—I don't say that the State Highway Commission will do what I suggested, I am speaking only as an individual—the State Highway Commission will designate where that money shall be spent as provided in the Federal Law. But the Attorney General says that if it is unconstitutional for the legislature to say that they will build a certain road, it is equally unconstitutional for them to attempt to delegate to the State Highway Commission a power that they do not have. So you see here is the next thing.

Then we come back under the Tice Law and we have a system designated of sixteen thousand miles. That was held by the Supreme Court to be a constitutional proposition because they said it benefited everybody, it is a general improvement. Those of you familiar with the local improvement law here know, for instance, that you could go into a town and build a waterworks system ,and if you leave out a few blocks you can get by as local improvement. If you put them all in, it is a general improvement and you cannot make it under the special assessment act. And we are trying under this system which has been held constitutional to get practically the whole system in the hopes that then this will be declared a constitutional proposition, and the legislature will be persuaded to appropriate that money to the State Highway Commission for its own use. And then you have to start somewhere.

Mr. Gabelman: What scheme or method does the State Highway Department use for selecting the types of pavement?

Mr. Marr: The State Highway Department has no authority. It does not attempt to select the type of road improvement.

Mr. Gabelman: Do you recommend any?

Mr. Marr: No. We do not.

Mr. Gabelman: Just let the counties pick them out at random?

Mr. Marr: They pick them out. All we do is to recommend that they study the various types, their limitations, their advantages, and their disadvantages. We refer them to the best that we know, and we recommend strongly and advocate that they try to get their types in some kind of a reasonable, rational relationship. That is as far as we go.

Mr. Gabelman: You don't try to tell them that here is a road with so many vehicles a day that ought to use brick and here is one with so many that ought to use gravel?

Mr. Marr: I don't know where you would change. We never got that far along in the state. I have been satisfied if I could get just a sort of a balanced-up system. I cannot see, I do not see how any one can tell the absolute limits of it.

Now, the best road talk I ever heard was given here at the Northwestern Congress just a week ago by the State Engineer of Maryland, and he explained that he was building a large amount of bituminous roads. He is resurfacing a lot of those gravel and macadam roads, and he is using penetration bituminous roads on the western side of Maryland. And some one made some remark about the eastern side of Maryland and he said, "Well, we build all concrete over there." "Why?" "Because we haven't any way of getting local materials there." And the local material problem is a mighty big proposition in itself. But where they have to import all their materials they found it more economical to build the Portland cement concrete road, and where they had local materials or where they could get their bituminous materials at a reasonably low cost and used fine matts and thin matts, oil treatments and penetration stuff, thin, one or two inches and all that, why, they found that more economical.

The change in character, change in conditions, temperature, and a number of other things make it absolutely impossible to set the limit either in numbers of vehicles or tons of load. But all over the country there is a general movement being made to note the action on every road by actual count on a ten mile basis and see about how much a certain type will stand. That will bring us a little closer to it. But for our purpose now we will do well if we keep them from sticking to one type.

Mr. Gabelman: Supposing that as shown on your map, where one road had two vehicles a day, and the other one two hundred, the county should decide on putting brick pavement on the two-vehicles-a-day road?

Mr. Marr: That is just about what they do.

Mr. Gabelman: And gravel on the two hundred vehicles a day road.

Mr. Marr: It depends on how they vote or something of that sort. That is the way it actually results. They do that.

Here is an illustration. Over here in Bureau County they took their allotment, which was enough to build six little chunks about a quarter of a mile each, went out six different ways from the county seat with a quarter or a half a mile of concrete road. Nobody got any benefit from it, and after they had determined on that and the State Highway Commission had fussed with them for a long time the Commission finally threw up their hands in utter despair and said, "Go ahead, go to it." When we tried to let the contract, nobody would bid on it.

Now they are beginning to understand that the concrete roads cost them twice as much as though they had a reasonable stretch of it. Nobody can go out and do it, any more than you can build a flag in a cement sidewalk for the same rate per foot as you could two or three thousand feet of it at the same price.

W. M. Kinney, M. W. S. E.: Have you figured out what the cost of maintenance would be to the state, assuming that all counties

adopted a system somewhat similar to that outlined for DeKalb County? Such a road program would be most admirable for the first few counties adopting it, but considering the whole state under such a system, would not the maintenance be prohibitive?

Under the present road laws, a large share of the maintenance burden for the first few counties adopting a road program would be borne by the state, but as the number of counties building roads increased, each county would have to be taxed for its share of the maintenance charges, and therefore might better start in with more permanent roads which would require less maintenance.

In the large eastern states which have many miles of macadam and gravel, the maintenance problem is a most serious one. We should profit by their example and build roads having low maintenance cost.

Mr. Marr: It is pretty hard to get anything definite about those roads in Massachusetts, because first, they have macadam roads there where they have no business to have them; second, they are overburdened to begin with, and third, they are not properly maintained.

We figure roughly about $75 a mile a year for the cost of maintenance, outside of the wearing surface—that is, trimming grass and weeds and cleaning culverts and ditches, and various repairs on bridges, etc., which averages about $75 a mile. We figure a concrete road to be around $25 a mile. We figure a gravel road to be where it reaches about its limit, somewhere in the neighborhood of $200 a mile. And I think on the average you might say $125 a mile throughout the state would be ample, and would give you $125 and $75—$200 a mile a year for maintenance. Our system comprizes sixteen thousand miles. You have then, according to that, $3,200,000 a year. Now, you are getting on your automobile fund at this time, $1,300,000. Without increase that will be $2,000,000 in a period of five years, or about 1920—up to 1920 following the rate of curve up until your point of saturation, there is no question but what you will be collecting $2,000,000 a year. The county will pay for a large share of that on these types of earth and gravel. So you have got ample there if the system were completed to pay for the maintenance, if I am right in saying $200 a mile a year for the whole system.

In New Hampshire they have a system of a thousand miles of gravel roads carrying somewhere between five hundred and a thousand vehicles a day, under a constant maintenance plan. They have better materials, I understand, than we have here, and have better construction. At least the man that was responsible for that system of roads there made this type a particular study. He was very careful about every detail, and got the best construction. Anyway their average is only $200 a mile a year for that thousand miles. Now, if we get sixteen thousand miles just think what that percentage means. If we had a logical, rational thing we would have about a two per cent system of Federal aid roads, which would give us our Z in Illinois.

Such a road could be made economically and should properly be maintained by the United States Government, though built jointly with the state. But we go at this from the wrong end of it. We build the roof of our house first as a rule. These County Boards build a concrete road, for instance, on a new grade that has not settled. It cracks. You don't get the full advantage out of your materials and the settlement of the grade. You don't get the use of the road to draw the new materials on it. A heavier pavement is required than would be necessary if the grade were settled. You know how that works out. As I say, we begin at the wrong end. Townships all over the state to the extent of some five to eight million dollars a year are voting township bonds. You know they are now building their roads without regard to the county system of roads. The counties are going along and doing as Mr. Gabelman suggests, forgetting all about the state possibilities of roads, and the state is going merrily on without much regard to what the Government is going to do—the state as a whole. If we would do this thing logically we would design a national system of roads of somewhere in the neighborhood of two per cent of the mileage, and which would give us about our system here (indicating the map), and we would have a five per cent system which would be a state system and would connect all the county seats, and that would be approximately this system (indicating) that I have outlined there. And we would have another system of ten per cent, which would give you one of your county designs like that (indicating) plus the state and the Government work, and the balance of it, which would be somewhere in the neighborhood of eighty-three per cent, somewhere around there, would be township roads, most of them probably dirt roads for years and years to come.

Now we are not going at it that way. I do not know why we are not, but we are not. The plan I have outlined would be better. I think we are coming to it.

E. J. Dowdell: What per cent of the DeKalb system comes under state maintenance and what per cent does the county have to pay—half of it or all of it?

Mr. Marr: I cannot tell you that because the system has not been adopted in DeKalb County. The state pays half the cost of maintenance on gravel and macadam roads and the county half. On the earth road the county pays the entire cost of maintenance, and on the concrete and brick roads the state pays the entire cost of maintenance. That is the law. As to any particular design, I haven't that.

J. W. Lowell, Jr., ASSOC. W. S. E.: After the county or the township has decided upon a type of road, does the State Highway Commission designate the specification for that type?

Mr. Marr: The State Highway Commission has the right of approval, a sort of negative power. If the County Board designates a road to be built with state aid then the state commission makes the plans and specifications and superintends the work. If the

county makes the plans and specifications the state has the right to approve or disapprove them. If they approve, then the county is entitled to receive back half the cost of construction from their allotment, to be used as they see fit, in repairing or building more roads, reimbursing themselves or paying off road bonds. In other words, the county is entitled to receive half the cost of construction if they proceed by adding new allotments to their bond issues.

President Grant: How many miles of improved road are there in Illinois now? How many in Indiana? And what is the method of getting those roads in Indiana?

Mr. Marr: In Indiana I think they are really worse off than most of the states. They have issued bonds there, in small units—township bonds, over fifty year periods, for gravel and macadam roads, and regardless largely, you know, of how important the road was. And they have had no means of giving it adequate maintenance. That is the local end. But the odd feature of that is that you cannot find anybody in Indiana who is dissatisfied with it. They are known as having forty to forty-five per cent of their roads improved, and they are all happy over there and are all willing to vote more money. And the people who go over there and go over those roads usually come back with the impression that Indiana is about the best state in the country. And they don't see any reason why people should be spending any more money. The reason is simply this that under the local plan they cannot use the equipment, they cannot take care of the maintenance—the two big features—and they cannot get the same rate of service that they could have in a more comprehensive design or a better handled plan. But they do not seem to care over there about the cost. It is almost impossible to get them interested in a state highway department. Townships don't want to loose their own control. And the voters themselves are pretty well satisfied on account of the service. They think the service is all right. It was illustrated there in Maryland, that the people that are getting gravel and macadam roads are willing at any time to vote more money and to place it in the hands of the state highway department and leaving it to them to spend it any where they wish. Under the Maryland law nobody has anything to do with the type or location except the state highway department. They say "We will build this road this year. We will resurface it, reconstruct it or relocate it"—or do anything they want. And everybody is satisfied. The reason is they are getting good service. Now, that illustrates the point that if you do give them service then the cost gets very little consideration. But if you go in for design, the cost is of prime importance, and then number of miles—they want to know how many miles they get and how much it will cost and they are very much interested in that. They are not interested in type. It depends, if they have gone over a lot of roads in Iowa, like so many people did going from the East to the West to the Exposition in San Francisco, they go through Indiana—fine roads, everybody talked about it. And they

go through Illinois—rotten roads, everybody talked about that. They go over into Iowa, all dirt roads—fine, good enough for anybody—the great roads of Iowa. And they are all dirt, all of them. They haven't any hard roads over there to speak of. But they are satisfied. Nobody pays a bit of attention to whether he is on an earth road or a brick road or what it is so long as it goes all right—smooth. As long as it is not a bad road it doesn't make any difference as to the type. If he has a smooth surface that is maintained properly he looses all interest in the type. If you go along macadam or brick or concrete or some similar sort of road people will almost instinctively turn out into the earth side road because it goes along so much nicer.

And when we are passing over the state boosting for roads, we try to instruct the chauffers on one thing and another as to what to do. And when we are going out advocating better roads you will see the leader of the procession, probably the governor guiding them, turn off onto the dry earth at the side. They do that almost instinctively, illustrating that what they want is a smooth, easy going surface, and they don't care a thing about the type, whether brick or concrete or anything else as long as it rides all right. When it is wet they don't go into the mud. They wake up. It is like the fellow with the leaky roof, they do not care when it is dry.

If we devote ourselves to constant maintenance of our roads and keep them in good condition then I maintain it reduces down to a commercial proposition of so much per vehicle per ton per mile, or something of that sort, and people will lose all interest in the cost if you give them service. Then it is up to the public officials to give them the most for the money.

I think we have somewhere in the neighborhood of eight or nine per cent of what we call improved roads. Now, our eight or nine per cent means we have got some sort of improvement, a little gravel scattered around the road. They call that an improved road here in Illinois. And in Iowa, for instance, they call the dirt roads improved. And they stand higher than we do, I guess, in improved roads, and they haven't any hard roads at all to speak of.

The different states send in reports to the Government about improved roads. It is pretty hard to make anything out of them. Indiana is credited with about forty-four per cent gravel and macadam roads, in pretty good condition. And they are well known for their good roads. We have, I think, about eight per cent improved roads. And we have got five hundred miles or thereabouts improved in Illinois under this state aid plan since the Tice Law went into operation.

Stanley E. Bates, ASSOC. W. S. E.: In balancing up all the different items like the population of the townships, the wealth or taxable property, valuation, and this traffic census to determine the relative importance of the various roads, what weights are given to these various factors? It just occurred to me the following pos-

sible case: A county might have, say, a large city in the northern half and a large city in the southern half, and at some previous time had improved that road connecting the two, with a macadam surface, because it is a good road connecting two centers of population—might have four hundred vehicles a day. Off in some other part of the county there might be a road that had but four vehicles a day but if that road that had the four vehicles a day were improved with, say, a good gravel surface, as might be recommended, it might draw enough extra traffic to make the gravel surface inadequate. In other words, improved roads draw traffic from some unexplainable place. They always attract a great deal more traffic than might be expected to come. And I presume that Mr. Marr has worked out some method whereby he decreases the importance of all improved roads in taking that traffic census, and other similar methods of calculation. I wondered what weights were given to the various points?

Mr. Marr: You mean where a road is already built and we take the traffic census on that road, how do we distinguish then as to whether or not that road is carrying more than a normal traffic at the time the census is taken?

Mr. Bates: Yes. In other words, if that road that is already improved with gravel, were improved with earth, or were not improved, I mean, the same as the more unimportant roads were, why, it would presumably carry much less traffic and the traffic would be distributed part over the other parallel roads.

Mr. Marr: Yes.

Mr. Bates: And yet they should be—the relative amounts of traffic that they bear at the time the census were taken should all be reduced to a common denominator as if the roads were all of the same character.

Mr. Marr: Well, here is about what we do. We have had, as I have showed you in the plat for DeKalb County, located the roads already improved. We do not try to get at it to such a fine point that we distinguish between how much that is carrying more than normal and what the other roads which are not improved are carrying. But we do try to take into consideration the fact that those centers are to be connected up and those are the roads that will carry the most of the traffic and serve the most people. That is only the backbone for our system. Then the others are in proportion.

Now, the point that you raise is very valuable and here is the way we use it. A township like this one, for instance, Afton, is right between two large cities. And here is La Salle County down here with other cities. That township has practically no people in it and yet there is quite a heavy through township traffic on that road. It so happens in this county that a concrete road has been built at the present time with state aid. Now, these people in Afton will get a gravel road possibly through here. The concrete road was put in La Salle County because the necessity for that road was

seen as soon as improvements were started, and they did it in a very logical way in this particular county, put it on the main traveled road north and south. Now, if that concrete road were not there it would seem to be that a reasonable distribution of that type would be to run gravel here, although none of those guides are criterions or anything that points to making the decision in any way. We just use the three or four different guides together with the local knowledge that we gain from these people representing the districts in order that we may reasonably balance the system. That is the only purpose we have. We do take into consideration, as I say, these other cities around there and how much more important one road would be than another.

And you asked another question in relation to the distribution. When you build a single road it is recognized that that road will immediately be drawing traffic from other sources to it. Now, if you design it for what you expect to come on it, and you are right about it, when you build your entire system of roads the traffic is re-distributed proportionally in its logical, natural channels and your road is over-capitalized; there is buried capital there. If, on the other hand, you build a single improvement here and invite a whole lot of foreign traffic on it, it is overburdened with abnormal traffic and your money is burned up in maintenance. So in either event your cost of service goes up for single construction. You are bound to lose one way or the other. But if you make a system of roads and adopt a reasonable distribution of types it is logical to suppose that that distribution will remain in natural proportion. We cannot get down to a fine point, but nothing much can be lost because we ought to learn in the space of three or four years how those roads are taking through traffic and how much the cost is to change the types.

Another thing in which there is a great advantage, supposing for instance you build your grade one year and put a surface there of local gravel, or local broken stone, whatever is available, you have the greatest advantage of all in the settlement of that grade. That is incalculable. Then the next advantage is that you have that road in service, and in service for probably two or three years before something else is needed to be put on it. The next advantage is that you have the use of those roads to draw material, which is the big cost in road building. These roads will take the hauling, and bring the new material for resurfacing or reconstructing. And in the next place you have a road susceptible of a lighter type of improvement due to the additional bearing capacity of your grade, than would otherwise be required if you completed the heavy type first. There are a great many advantages.

Handling the proposition from the county viewpoint, the county wants the roads built where the most people use them. There is a demand and a necessity for through traffic roads which cannot be built by small units because a continuous road is not of equal im-

portance to each of the units through which it passes, and the individual units are not equally well equipped financially and otherwise to build the economical type for the road as a whole. There is a logical distinction between a national, a state, a county and a township road, and the smaller units such as states, counties and townships cannot be brought to act in harmony with a comprehensive plan where their views and interests are at variance and there is no centralized authority.

As a matter of fact the usefulness and efficiency of the motor vehicle are limited by the length and continuity of a road, and further limited by the condition of the road, which depends on proper maintenance, and which maintenance in turn depends on central control. Inasmuch as the motor vehicle pays half the cost of state aid roads it would seem right and proper that it should get something suited to its needs, especially in view of the fact that townships are relieved almost entirely of the first cost, maintenance cost and renewal cost. But the vital thing is to get the roads built in proportion to the benefits and in proportion to where the cost is derived.

If you had a two per cent system it would be perfectly proper for the government to build that two per cent system. All the people of the country are paying for that and that would be reasonable because there would be a certain amount of interstate benefit. And, as was suggested, the military use of a national system would be for the benefit of all the people. It would be a two per cent proposition and all the people would pay for it.

We come in here and get a five per cent proposition, and some of the fellows in here (indicating on the map), some whole counties don't get any of that five per cent system, but they pay for that because it is for the benefit of the whole state. It is a state proposition. And they pay that little bit, which would be two or three cents an acre and would not amount to anything at all over a twenty-year period.

Then they come along with the county system of roads, and you don't touch every township. And in some townships like this one I showed you here you would have to build a concrete road, not because the people need it in that township, but because the people of the county want to go through there and want to have a type economical for the county. It is a county proportion and not a township proposition.

Then you pass to the township proposition, and they build a system of roads, and vote a bond issue for the township and build those roads, and then the highway commission tacks on a 61 cent levy and drags the balance of the road. There you have the distribution of the benefits in proportion to the cost paid by the individual. Ultimately you get a system here of roads that will represent the benefit in proportion to the cost.

Under the local improvement plan, for instance, take paving here in Chicago, you build a street improvement. That is assessed,

in most cases, except in a few, straight on the property, the near surrounding property, at any rate, almost on the front foot basis. They pay for that. Ultimately the whole city is paved and the distribution of benefits is reasonable in accordance with the cost. If you go into this proposition they all start to pay this state aid. They pay in the whole county. Then the county takes the proposition, and they build roads where they are most needed. And as you go on down the line they will ultimately get their roads out to every farm house, and they will get them where they need them most and in the logical order where the people are paying for thm. The others will get a benefit. Out at the outlying districts of the township they will get a benefit at least in proportion to what they pay. But don't forget that they are paying now 61 cents on $100 valuation as a township tax. And if you take the main lines, supposing this to be a county proportion, now, instead of a state proposition, and they pave the main lines and then take right away 30 or 40 cents off what is being spent now on these same roads through lack of proper equipment and men constantly employed, and spend that money economically—they are spending 61 cents, and more than half of it goes on those main lines, the rest of it being so scattered that nobody realizes what is done. They drag it here and there once or twice a year now and their money is gone. Now, if you reduce that tax from 61 cents to 30 cents and build your county system, you will accomplish something. It is a clear case of getting something for nothing. It is a fact, there is no getting away from it. You get it out of the saving in the present waste.

A Member: What is the reason that Indiana has built the greater per cent of her roads out of macadam?

Mr. Marr: Local material. They have it all there.

The Member: Does the soil there afford better drainage than Illinois?

Mr. Marr: I would not say that it had any better natural drainage. The substratum there is rock. They have so much local material available, and they have a great advantage in having lots of things that we could well learn from them.

To begin with, they go out with their township commissioners and their sleds in the wintertime, or any time they can get teams for the least money, and bring this crushed rock or gravel, prepared also economically, and dump it right in the middle of the road. After two or three years they get a pretty good gravel or macadam road, the traffic beating it out. They do not give much attention to drainage, and they have not a high rate of efficiency, but the people are satisfied. It only costs a few thousand, one or two or three thousand a mile, to build those roads. Now, we try to build a macadam road without any water, and to build a gravel road without any clay in the gravel, and we spend five or six thousand dollars a mile, and the township commissioners will come out and say: "Well, is that the best you can do? Here you have spent four times as much as we did, and look at it." It takes three or four years for

our gravel and macadam roads to get in good condition like theirs where they have just dumped it maybe in the center. And they do not mind driving over those humps until travel smooths them out. It does not cost much. We cannot expect anything more from our methods. After six months our gravel and macadam roads are usually shot to pieces. The value is there all right, and they can be dragged and be brought into condition, and after a year or two make a good road like theirs, but we have paid three or four times as much. We do not see the value in them at first. We get no end of criticism for that sort of thing.

V. M. King: Have you given any consideration to the cost of hauling, assuming this millenium, which I am afraid will not come in our lifetime—but say all of these counties had all of these roads built, it seems to me we have to figure it back on the actual cost of hauling over those roads. That has to be considered. We have also to consider the farmer or merchant who may be, for instance, located on the dirt end of a road that ends in brick or concrete. Now, that fellow has to start out with a light load. He has to carry the load that the dirt road will carry. Some recent experiments made at the Massachusetts Institute of Technology show a great deal of difference in the various types of road so far as the tractive element is concerned. It seems to me that that has to be considered along with the question of cost of hauling and your matter of population and various other things.

Mr. Marr: We regard that as involving the time element. The earth road, when dry, sustains any of our loads. Now it is a question of keeping it dry, and that is a matter of dollars and cents largely. You can do it by proper dragging, or by the use of oil or something of that sort most of the time. We figure roughly that the earth road, as usually built by the township commissioner, is in good condition 150 days a year. That is not the ideal grade. If we give that road the proper grade, so that it drains well, we can get another 75 days' service out of that road. That makes about 225 days service, roughly speaking, in the broad average. Then we use oil or some such method, and we probably drag to keep it in condition, and we get another 75 days, or about 300 days service. Now it is out of service about two months—by service I mean service equivalent to brick or anything you can build. When it is dry and hard you would not want anything better for any purpose. And if you get 300 days service, it is a matter of what it costs, and that has to be figured out. When it is in service you can draw on that to the end of your brick road except for that couple of months.

Mr. King: Not the same load.

Mr. Marr: Mighty near it. Of course you get the heavy grades involved in there. But when a road is in pretty good condition, all this talk about tractive effort and all that sort of thing involves the time element more than anything else. If you use oil it will take your loads all right. I do not think it is anything like as significant as commonly supposed by those who are just taking the mathe-

matical end of the proposition. Now for two months you are out of service, but that does not mean you are out of service entirely. And what we claim is that when you get a road in pretty fair condition as to grading and the amount of oil on there, you may go into the mud, but you get through it, you will not just sink out of sight and stay. Whether you sink in an inch or two or five or six inches does not make much difference, and involves the time element more than the tractive element.

J. W. Pearl, M. W. S. E.: What type has the lowest service cost?

Mr. Marr: They ought to be all the same if we can figure. We are attempting to get a uniform rate of service. Where the heavier types are used it is because of the greater number of vehicles or the greater tonnage that is carried. That involves a higher first cost and higher powers of resistance to abrasive effort and to destuctive action by traffic. We are attempting to have the rate of service uniform. In other words, we say that when a gravel road is designated it is placed there because it will economically serve the people with the amount of traffic going on it. And the rate of service ought to be the same for all the different types. That is, of course, it is not possible to determine the type with extreme accuracy or anything like that, but we are just trying to get something reasonable rather than going from one extreme to the other and saying they have to be all brick over the whole county, which is impossible, or all roads of any one type. To meet all the different conditions we cannot have one type. We must vary those types for economy. We are aiming to make the rate of service approximately constant.

Mr. Dowdell: In other words, your rate equals first cost plus interest, plus maintenance, divided by traffic equals constant.

Mr. Marr: That is what we are aiming at. And we are neglecting features of local sentiment, and the esthetic features—noise and things like that that enter into the city problem. We always advocate as a business proposition the use of local materials in so far as they are of value. And there is a mighty big distinction between value and price, which is worth a whole lot of study. Price and value are very different in a great many cases.

ADDRESSES AT THE ANNUAL DINNER OF THE WESTERN SOCIETY OF ENGINEERS

January 24, 1918,

By Major Henry Jackson Burt, *Retiring President.*

It is one purpose of my address tonight to bring before you some idea of the achievements of this Society, and to present a vision of still greater usefulness, so that you may have a better appreciation of its past work and an ambition for future development. This to the end that you will see the need of keeping the work of the Society in full swing during the war. Another purpose is to set forth some of the problems incidental to and likely to follow the war.

In speaking of the accomplished work of the organization, I shall not attempt to give a history of its career. There are other members much better fitted to do that, and the subject properly belongs to the approaching semi-centennial celebration. I shall only give brief reference to its growth, its work, and the work of a few of its distinguished members.

We are entering upon our fiftieth year. That in itself speaks volumes. No institution depending on the voluntary action and activity of its members can live so long unless there be ample reasons for its existence, and unless the results attained are valuable. We need seek no further than this for justification of its existence. Such a period of activity establishes its permanence.

Its growth can be compared to that of a tree; not like a forest tree, whose beginning is from the chance placing of the seed by Nature and whose growth is controlled by the accidents of environment, warped by a multitude of surrounding conditions. It is a tree from a selected seed, planted for a specific purpose, nurtured by the best brains of the profession, and cultivated by the hands of those vitally interested in its development, set in a field where its growth is unhampered.

Its growth has been steady—and when I speak of growth, I do not refer alone to numbers and treasures, but to stability, traditions, influence and usefulness. It is true that there have been dry years, years of less activity and little progress. These have served to harden the structure and prepare it for a more vigorous progress rather than to stunt its growth.

The past year, in some respects, may be considered a dry one. Nominally there has been a decrease in membership, due to the pruning out of an accummulation of dead limbs. Apparently there has been less activity and interest in the technical meetings. This is a natural consequence of war conditions. Neither of these items need to be viewed as retrogressive. The loss of numbers has prepared the way for a more vigorous and wholesome growth which is already beginning. The slackening of technical work will change to increased activity as we adjust ourselves to war conditions.

In other respects the affairs of the Society have been normal

or better than normal. Although expenses have been a little more than earnings, they have been considerably less than the collections. By a vigorous clean-up of over-due accounts, we have been able to invest $2,000 in Liberty Bonds. The calls of war have received a creditable response both from the organization and its members. Regular and special committees, as well as the office staff, have devoted much time to war work with effective results. The response of our members as individuals is partially shown on our Service Flag. It contains nearly 100 stars, representing all grades from private to major-general. These are men actually in the military service. In addition there are many doing war work as civilians. In fact, it may fairly be said that a large proportion of our members are doing some special service or making some considerable sacrifice for the cause.

I believe the war activities of the Society and its members have added much to its standing and influence.

I might speak at some length of the good work of the board of direction, the committees, the secretary, and the office force: I might tell of the reorganization of our business methods, the constructive changes in the library, the prospects for increased technical activity, and the outlook for growth in membership, but mere mention of these items will have to suffice.

In years gone by the activities of the Society have been chiefly the exchange and publication of engineering information. To that end it has held meetings, published a Journal, and acquired a library. There is nothing spectacular in such things; not many items outstanding in importance; little to attract public attention. It has been just steady work of ever increasing value to its members. In spite of the modest way in which its work has been done, the Society is well and favorably known to the profession at large, and is becoming well known to the public of this community and commonwealth. The policy heretofore maintained, of holding aloof from participation in public affairs has operated to prevent a very general knowledge of our existence. Where known at all we are favorably known, and have standing and influence accordingly.

The Society may be considered as the composite of its members. Its standing, influence and usefulness are but the reflection of these attributes of its members, more especially of those who have attained distinction in the profession and those charged with its administration. You need, therefore, only refer to the Year Book of the Society, and read the names of its past officers, to appreciate the enviable position that it holds and is entitled to hold. The men who have builded this organization are the men who have been the leaders of the profession during the last half century; to name them and their works individually would be to name them by the score and to catalogue most of the large engineering works of the country since the Civil war. We have in our list many of the leaders in engineering education and engineering science.

This list is impressive. Volumes could be written about these

men and their works, and it is my ambition that this Society shall foster the writing and publication of such volumes. We owe it to them to do so, and we owe it to them that we continue their work.

I wish such men as Herr, Bates, Randolf, Hunt, Alvord, Wallace, Carter, would lay aside their modesty and write their own stories. What a wealth of information and inspiration they could give us! What a treasure it would be if we had such records of Sooy Smith, Noble, Corthill, Cooley, Chanute and others who are gone!

It is the professional success, the personal integrity and high character of such men as these that has given this Society the good report that it enjoys. The rest of us, by being admitted to membership with them, share the glory. It is, therefore, incumbent on us all to rise to the standards they have set and add something to the luster for the benefit of future members and the glory of the profession.

Success is a relative thing. The high-grade work of today will be common tomorrow and mediocre the day after.

A society, like the individual man, cannot be stationary. It must forge ahead or fall into decay. There is no room for difference of opinion among us as to the direction in which we wish to go.

We must move forward, we must maintain our activities in spite of all the difficulties imposed by the war. This means that every one of you who stays at home must devote more than the usual amount of energy to the Society's affairs. If you individually will respond to the call, the work can go ahead with increasing usefulness. This is a time for individual responsibility. It is no time to lay back and leave the burden for your brother to carry. The member who is unwilling to work, if there be any such, is not worthy of membership, and he who does not respond to the call or does not volunteer when he sees an opportunity of service, is not rising to the situation.

You have more than a hundred men in the service. Before the year is out you will have double that number. Many of these members cannot pay the annual dues. What a fine spirit it would show if, for each one of those in the service, one of you at home would assume the burden. This would be far more creditable than leaving it to be borne by the Society. The financial scheme of the Society is not designed to stand such a drain. Its reduced income and increased operating expense make it inadvisable to allow such a draft on the treasury, but it will have to be borne by the treasury unless the individual members accept the load.

The same spirit of taking the absent member's burden applies equally to the technical and committee work of the Society.

There are hundreds of engineers qualified for membership in the Western Society of Engineers who have not yet affiliated with it. They are missing an opportunity of improving their own professional standing and of co-operating in the necessary work of maintaining and advancing the profession. This support is needed

now and it is the duty of every member to assist in bringing them into the membership.

This year, and the one, two, three or four following, are likely to be the most notable in history. The greatest crisis of civilization will reach its climax in one of these years—years replete with tragedy, romance, passion and sacrifice, evolution and revolution. What will be the outcome? We are all confident of the outcome of the war, though our confidence is based more on hope and conceit than on any substantial basis of facts and conditions.

Whatever the direct outcome of the war, there will follow in its wake some of the greatest problems with which man has had to deal. There is likely to be as great a revolution in this country as we hope there will be in Germany. Perhaps it will sound less harsh to call it *evolution*—a peaceful evolution, I hope. As war measures, we have invoked some of the extreme measures of Socialism—practices unbelievable a few years ago. Will we give them up when the war is over? No; not altogether; that is neither to be expected nor desired. The problem then will be to retain what is good of these measures and discard that which is pernicious.

We have government control of industries. To what extent is this desirable in times of peace? It has been tried during years past in the case of railroads and in the case of so-called trusts, and has not proven altogether successful. The ideas of regulation which have been prevalent heretofore are in many instances being directly reversed. Co-operation between large industris of th same kind, which has heretofore been forbidden, is now encouraged. Will we develop from the experience of regulation before the war and of regulation during the war, a sane system applicable to peace conditions which will foster industrial development, and still produce an equitable distribution of the fruits of industry? This is no small problem, and it will require wise heads to properly interpret the experiences we will have had and apply them successfully during our reconstruction period.

We have a limited government control of the distribution and price of food. As the war goes on this will become more rigid, and may extend to the extreme condition of rationing all our people. Is it desirable that this be wholly or partially a permanent function? As a war measure it is an absolute necessity, for we have not yet risen to that height of perfection where each of us will take only his fair share, taking care to leave for all others their fair share. It is only a natural disposition that each individual shall look after himself and his dependents, without giving much consideration to the welfare of others. We have had for years an evergrowing tendency on the part of those engaged in production and distribution of food to manipulate their business in the interests of their own financial gain and against the interest of the consumers. The smallest groceryman seems to have prospered far beyond the hopes of the average professional man, and the large distributor has profited entirely out of proportion to the intelligence and financial investment involved

in his business. Will the unquestioned benefits of the rationing system become a permanent institution, or shall we lapse back into the old system, and control the situation merely by public sentiment.

We have government operation of railroads. Is this another stepping stone toward government ownership? At the present moment it is a vital necessity, in order that the whole transportation system may be operated as a unit in carrying out the one great purpose in which we are engaged. The government control of railroads has been increasing during the past quarter of a century so that the step recently taken is not an extremely radical one, and has been accomplished with no particular demoralization. It would seem to be a comparatively simple matter to take the next step of substituting securities pledged by the people of the United States and their combined property, for the securities which now represent the ownership of the railroad properties and thus transfer the ownership to the people. This part of the program is comparatively easy, but does not settle the question as to whether the state operation of railroads is a practical thing.

It is perhaps very fortunate that we can have an opportunity of government operation during war times, to serve as a trial, without being committed to it as a permanent thing. From this trial we may be able to decide with more assurance than we could do from abstract study of the subject, or from the experience of those countries which have tried government ownership. The economists interested in this subject will have a most valuable opportunity for studying the experiment. It is true, the experiment will not be under normal conditions; but the conditions will be such as to make it possible to interpret the results with some degree of certainty.

We now have a partial government control of labor. Soon, I believe and hope and pray, we will have full control. Shall we, after the war, have government control of labor in the interests of the common good, or shall we have labor control of government in the interest of labor? The governmental tendency in recent years has been to bow to the dictates of labor as a matter of politics and expediency, with the result that we have today the astounding situation of labor organizers calling strikes on the emergency work of war. Treason is a gentle name to apply to the men who call such strikes, and mutiny is a soft term to apply to the workmen who lay down their tools at the dictate of those traitors. Preliminary warnings have already been sounded, and it will require but little more disturbance of this character to bring about the conscription of labor for all emergency work. I do not suggest this in the spirit of threat or retaliation, but in the spirit of universal service, for I believe that at this time there should be a definite place and a definite occupation for every citizen of the United States—a place just as definite as if all were members of the military organization. I believe that it would be entirely proper that every farmer should be told how much he should plant in one crop and how much in another; every mechanic should be assigned to the job on which he

should work, and the hours he should devote thereto; every merchant should be told what goods he should sell, at what price and to whom; the manufacturer should be controlled as to what product he should turn out from his factory, and what quantity he should produce, and what labor and materials he should employ. So my suggestion of the conscription of labor is not a measure of retaliation or coercion, but simply one of the elements of spreading the burden of universal service equitably over the whole people.

Out of the experience we are having and the experience we are destined to have in dealing with labor, will we develop a relationship that is equitable, and being equitable, can be made permanent? If this cannot be done, we will tend toward control of the government by labor, in the interest of labor. This would not be a serious thing if the term labor could here be used in its broad sense, but unfortunately, it must be used in its restricted sense of organized labor, whose purpose it is to advance the interests of a relatively small number of men banded together for the avowed purpose of gaining an advantage out of proportion to their normal merits.

We have an inflation of currency, or credit, if you choose, based on our common wealth. No one is now asking how much gold there is in the United States treasury. Before the war is over gold may have very little to do with our circulating medium. Will the trade of the future be conducted in terms of a metal of little intrinsic value, or in terms of fiat money based on public credit, and expressed in a unit representing a definite measure of human labor and the essential commodities. As I see the situation, it would be one of the greatest possible economic blessings if we could now have a medium of exchange on such a basis, rather than a medium expressed in so much yellow metal. How greatly the burden of the future would be reduced if the obligation which our Government assumes today in securing a day's labor or a bushel of wheat, could in the future be liquidated by a day's labor or a bushel of wheat, plus, of course, the interest for the intervening period. But such will not be the case; every day's labor and every bushel of wheat now being used in this emergency for the common good will require on the day of reckoning two, three, perhaps four days' labor and four bushels of wheat to settle the score. We cannot escape this result unless we repudiate our obligations, which we will never do, or unless the present relation of money to commodities is maintained, which is improbable, or the wealth of the country confiscated under the guise of communism. The solution seems so impossible that we must expect to pay two, three or four-fold.

Before the war is over an idle man or woman will be rare indeed. Practically all will be engaged in some useful occupation, regardless of wealth or social position. By useful occupation I mean some activity related to supplying the reasonably essential commodities of life and the needs of war. Gradually the manufacture

of luxuries and other non-essentials will be eliminated, not by direct enactment, but by lack of market, lack of materials and lack of labor; as the demand for essentials becomes greater, the demand for non-essentials will become less. This will take care of itself automatically. As the demand for labor to produce essentials becomes more and more pressing, public sentiment will force industry upon all of those who have not already enlisted as a matter of public spirit. For the majority of people this will make no change from their usual occupations, and it is well that the change should be a minimum. The disturbance is violent enough at best, so that those who can continue in their normal occupations should do so. However, those who have had no normal occupation which falls within the needs of the times must shift to something new, considered useful; also those who are not expending all of their energies in their normal occupations can do something additional, either in their own line or in some other manner. This latter applies particularly to women, many of whom because of their light responsibilities under normal circumstances, can devote a great deal of time in making wearing apparel or other necessary things, or in meeting the demands of social work, Red Cross activities and charities; or can take the places of brothers and others called into the service, as many are doing. We must "Keep the Home Fires Burning," as expressed in that song which has been so popular among our neighbor Canadians. This charming expression in common thought simply means to keep things running in the normal way as nearly as possible.

A great many of our people are eager to get into government service, and many have jumped into it without stopping to consider whether they can be more useful in that service than they can be in their regular occupation. The affairs of the country must go on in as nearly a normal way as possible, in order to furnish the foundation for the extra activities of the war. Nothing would terminate the war more quickly to our disadvantage than to withdraw the farmer from his plow, the weaver from his loom, or the driver from his locomotive. We have learned a great lesson from our allies in this regard, and an effort is being made by the Government to conserve its human resources by keeping people in their proper positions, and by using those who enter the service in the positions they can do the most good. This has not been accomplished in all cases, for we see many instances where men have been given duties far below their ability, and others where they have been assigned responsibilities far in excess of their capacity.

Public spirit and public sentiment are ridding us of our idlers, and we have about us a spirit of industry never before realized. Can this condition be maintained, or after the war will the pendulum swing to the other extreme, and leave us with an army of idlers?—idle rich and shiftless poor.

A large percentage of our doctors have been drawn into the service, and the question is sometimes asked, What will the home

folks do for proper medical and surgical attention? A part of the answer is that the need of it will be much reduced, for one of the effects of our preparation for war is the development of better health. The difficulty of procuring foodstuffs, both because of their scarcity and price, is leading to simpler living, which is directly conducive to better health. Greater activity and better care of ourselves should produce the same results. The health dividend resulting from this great enterprise will be a great one. This much can be said generally. For the men who are actively engaged in the military and naval service the result is something wonderful. We are building up a physical manhood in these hundreds of thousands of young men which has not been equalled in any country that has not had universal military training. Pallid clerks raised in city atmosphere and accustomed to the sedentary life of office work, are being turned into men as rugged as those who typify the outdoor life of our Western Country. This one thing alone will justify all the expense and time involved in universal military training. Every young man of this and future generations can well afford to spend one year or two in intensive military training for the physical benefit alone that he will derive from it. This training, if properly conducted, will give him a constitutional foundation of good health, and will teach him how to conserve his health. The military portion of it is essential as a matter of organization and discipline, quite apart from using that training for war purposes. There is no more reason why we should look upon universal military training as an incentive to war, than that we should view an athletic club as an organization of pugilists.

Will we miss this opportunity of making permanent things which have been introduced as war measures, but which will be invaluable in the conservation of health in peace times?

We now have some very definite restrictions in the use of intoxicating liquors. These restrictions are likely to become more and more rigid, with a fair prospect of absolute prohibition throughout the United States. Putting aside all considerations of personal liberty, and viewing it simply as an economic matter, this is one of the greatest developments in our economic history. Without definite knowledge of the figures involved, I venture the assertion that the economic saving from prohibition during the period covered by our war bonds will be enough to pay the cost of the war. A friend of mine who is at the head of one of the great manufacturing industries of this country, has told me that he estimates its loss, directly chargeable to intemperance, to be three hundred thousand dollars annually. In this amount is included only the lack of efficiency of the men while at work, and the partial idleness of the plant due to lack of full operation. It does not take into account the direct expenditures of the men themselves, the waste of the foodstuffs used in the manufacture of the beverages which they consume, nor the general economic loss due to their idleness. These items would amount to several times the direct loss to the employer.

Is it worth while that the benefits which we enjoy temporarily in this matter be made lasting? It does not follow that to accomplish this result we require universal prohibition, but perhaps that is the most certain way to accomplish it.

These are some of the elements that are developing as corollaries of the war. If wisely guided in their development, they may result in permanent benefits that will more than justify the cost in suffering and treasure that we are destined to expend. If allowed to drift or fall into the control of self-seeking or incompetent leaders, they may lead to stagnation that will make our sacrifices all to no purpose.

No single man or small group of men can solve these great problems. No single man has sufficient breadth of view to be entrusted with the solution of any one of these great problems. It will require the study of many men to solve them—men broad enough to see all sides, and fair enough to seek a solution for the common good.

All of us can help on this job. Each can select the problem toward which his talents incline him. He can study it and discuss it, and thus get others to thinking. From such consideration the solution may be evolved. Many problems seemingly very intricate can be unraveled by patient attacks of details at close range, more readily than by formal attack. As we carry on the work of war, let us give some thought to the problems that it brings, to the end that these things may have some guidance and a fair solution.

For more than a century this country has been the melting pot of the races of the earth. Here the various peoples have been thrown together and amalgamated in the citizenry of the United States. Now the whole mass is again thrown into the melting pot, and subjected to the intense heat of the greatest conflagration that has ever swept over the earth. The melting process is necessarily accompanied by sacrifice and suffering. As individuals, we for the most part, accept these burdens voluntarily, for the most part silently. There are some among us who are reluctant to expose themselves to the rigorous treatment, being satisfied to reluctantly hand out a small contribution to the Red Cross, or to invest in a Liberty Bond with one hand while they reach forth with the other to grab some advantage. This element I believe to be relatively small and becoming smaller. Before long I hope we will all be in the melting pot to become atoms of the final amalgamation, and when the war is over, I hope there will be tapped from this pot a refined metal and a refined metal only. Let the dross be dumped into the sea. And this refined metal, let us hope, will represent the highest development of civilization that the world has ever seen; a civilization of a unified people, all interested in the common good, ready to make sacrifices for each other; then we will have paid a great price, but we will have paid it for a great prize. Then the suffering of the mother who gives her boy; the sacrifice of the man who gives up the competence he has laid aside and dooms himself to an old age

of hard work; and the supreme sacrifice of the man who goes forth to be mutilated beyond repair, or to yield his life, if chance thus falls, will not have been in vain.

In closing permit me to express the appreciation I feel for the privileges of serving as your President during the past year. It is an honor much to be coveted to thus be entrusted with a share in shaping the destiny of such a splendid organization. It is no small favor to be allowed to be thus intimately associated with the work of those leaders of our profession who have developed this fair structure. I would be happy indeed if I could feel that my service had been reasonably commensurate with the honor you have conferred on me.

It is with much satisfaction that I now yield to my successor. Our affairs now go into the hands of a man of the highest professional standing; a man of the greatest personal integrity; a man competent to guide us during this trying period; a man whom we all can gladly support. For myself and for all of you, I pledge to him the support and co-operation that he needs for conducting our Society through the coming year.

By Mr. Charles B. Burdick, *President-Elect.*

January 24, 1918.

To the Western Society of Engineers:

Gentlemen: It is with much regret that I shall miss the opportunity to personally address the Society upon this, the only occasion during the year, when a considerable number of the membership is gathered together. This is a time, however, when all of our usual activities must be subordinated to the necessities of the war. Comparatively speaking, there is little that we can do as a Society to promote victory, and it is important, therefore, that the members as individuals should not miss the opportunity to furnish a personal service when this is possible. I should feel sorry, indeed, to be absent from this meeting were it not for the fact that my absence is made necessary in the promotion of a cause that is so close to us all and so imperatively demands promptness of action for success.

I further regret that my absence will come at a time when the activities for this year are being planned, for the honor that you have bestowed upon me carries with it the responsibility to represent you in the conduct of Society affairs at this time when the Society can accomplish much or accomplish little, depending upon the direction of the activities undertaken. Our constitution, however, provides for the conduct of affairs in the absence of the President. Therefore, while I regret that I cannot receive the benefit from a personal participation in the Society affairs, the Association will not be the loser, and possibly our interests in the war may be ad-

vanced in some small measure through my efforts during the next few months, along lines for which my experience has fitted me.

At the outbreak of war there was a feeling among engineers that society activities should be curtailed. This was in line with the move for conservation in all things not instrumental in winning the war. Further experience, however, has shown that while waste should rigidly be cut off, the support of the armies can be secured only through industry and so far as possible, prosperity at home. It is undoubtedly desirable to make the War our first consideration, and to shape our activities so that directly we may be of the greatest use. We have done our part in directly assisting the cause during the past year through the participation of more than 10 per cent of our membership in war activities, and 5 of our 15 directors, who are personally engaged in the government service. In a larger sense, we are all in the government service, and the opportunity should not be lost so to direct our efforts during the coming year that they will produce the largest return.

To be most effective our membership must continue to include not only the representative engineers of the West, but the rank and file as well. Since its inception, the Western Society has grown steadily except for a few short intervals of industrial depression. With these few exceptions, the roll of our membership has more than kept pace with the development of this community. The present is a time when our soldier members find it difficult to continue their support to the Society, and some lines of industry closely related to the building trade are quite inactive. Therefore, unless the Society shall suffer through a reduced membership, it rests with us, if possible, to increase the usefulness of the Society to its individual membership, thus making it possible to interest new members and to advance the science of engineering and the best interests of the profession.

I am sure that this administration is heartily in accord with recent efforts of the Society to interest particularly the younger engineers, for they will make the Society of the next decade. As a Society, we can do much for them in matters relating to employment. The itinerant character of our employment, the continued moving from job to job, is one of the least desirable phases of engineering as an occupation. Undoubtedly the Society can do more to relieve this condition than it has attempted in the past. During last summer, in connection with the construction of the Rockford Cantonment, the writer's firm had occasion to expand its force to about 100 men, a problem of considerable difficulty in view of the temporary nature of the employment. Without doubt there were scores of young engineers who, for no other reason than patriotism, would have been glad to have been connected with this work, and who would have found it possible to be temporarily relieved of their existing obligations if the matter could have been brought to their attention and to the attention of their employers. The men were secured principally through correspondence with employers.

In a sense, however, it is a reflection upon the Western Society of Engineers that it did not occur to us to apply to the Society for aid in this matter. At the present time it is understood to be difficult to secure the right man in the right place at Washington under the greatly expanded activities incident to War thrust upon this country unprepared. The Society has assisted materially in passing upon the fitness of engineers for the Officers Reserve Corps. It is believed that more can be done in the canvass of available men for particular tasks.

In devoting our main energies to the War, we must not overlook other ways in which we may advance the public interests. Our usefulness to the Society, the public and to ourselves, will be directly in proportion to our interest in and study of public matters where technical experience gives us an advantage over the layman. Controversial discussion of public matters should be avoided. The experienced engineer is quick to recognize that the solution of large problems requires study and research, and, therefore, he respects the opinions of his capable brethren, who in the exercise of their profession, have been afforded the opportunity for investigation and study. There are many technical matters of vital importance to the public upon which there is little or no difference of opinion among well informed engineers. We should endeavor to lend our aid directly or indirectly in such matters. A case in point is the recommended adoption of the meter system for the sale of water by the municipality of Chicago, which for years has been urged by the City Engineer and which has been commended by practically everyone conversant with public utility business. A recent report by the Chicago Bureau of Public Efficiency estimates that the net saving to be effected by the meter system would amount to $7,600,000 in ten years, $41,900,000 in twenty years, and $135,000,000 in thirty-three years, and this is without curtailing the use of water in any way, but upon the contrary, making water available to everybody, which has not been the case, or has not been until very recently.

Each year the highway problem becomes of more and more importance. As taxpayers and users of highways, we are interested in this subject, and the science of road building would be benefited by a more general application of the scientific principles that engineers have applied to other activities. Millions of dollars are being spent each year for new highways and bond issues and appropriation for this purpose are mounting at a rate that would have seemed incredible a decade ago.

There is a tendency to over-estimate the importance of new construction and to minimize the question of road maintenance. It is often incorrectly assumed that the abominable macadam roads now existing over large areas in the middle west are perfectly useless, and that good road service must await the millennium of a universal hard road system, whereas a comprehensive, intelligent maintenance and construction program, like that recently adopted

in Wisconsin, would produce at least a fairly good road system almost at once. Expenditures for new hard road surfaces could be made from year to year on those roads where the investment would produce the largest return in maintenance saved.

The application of engineering principles to this problem will disclose the fact that nearly every type of road has its proper place; that the best road investment is a proper balance between fixed charges upon the investment and the cost of maintaining the road in good repair. The amount of traffic vitally affects this problem and, correctly solved, the so-called hard roads would be indicated upon the main lines of communication and there would be an important place for old road types, slightly modified from the days of horse drawn vehicles. The New England and Middle Atlantic states are far ahead of the West in this matter, and as a Society, we can perform a service by promoting a better understanding of the road problem in our locality.

This is a day of rapid change. The necessities of the War have brought about numerous alterations in the conduct of affairs, any one of which would have been revolutionary three years ago. The War brought us face to face with new conditions and new problems, and when peace comes we shall doubtless find changes in industrial conditions that will inspire the greatest efforts from the engineers. As Mr. E. J. Mehren recently pointed out to us, the engineer has confined his attention to materials, and the layman for years has directed the human element in the problem of industry and he has signally failed. May it not be one of the important undertakings of the future that scientific principles shall be applied to of labor problem.

I would be callous indeed if I did not have the highest appreciation and the greatest sense of obligation to the members of the Western Society, for the confidence expressed in electing me President. If I may succeed, it must be by the aid of the counsel and help of my fellow officers and the membership. I pledge you my best effort to utilize this co-operation.

Secretary's Report, January 24, 1918

Board of Directors, Western Society of Engineers:

Gentlemen: I respectfully submit herewith the annual report of the proceedings of the Society for the year 1917.

The membership of the different grades and of the Society as a whole, December 31, 1917, is shown in the following table:

Honorary Members		3
Members—		
Resident	405	
Non-Resident	245	650
Associate Members—		
Resident	123	
Non-Resident	77	200
Affiliated Members—		
Resident	22	
Non-Resident	9	31
Junior Members—		
Resident	57	
Non-Rresident	30	87
Student Members		46
Total		1,043

Death has claimed the following members during the year:

Lyman E. Cooley, Past-President, died February 3rd.
Walter Katte, died March 4th.
Charles S. Hall, died June 15th.
Ernest L. Ransome, died March.
Charles C. Stowell, died August 11th.
Robert Kunstman, died October 21st.
Joseph S. Sewall, died December 23rd.

Thirty four meetings were held during the year, with speakers and subjects, as follows:

Wednesday, January 10 (No. 955)—Annual meeting, held in the Louis XVI room of the Hotel Sherman. "The Engineering School and the Engineer," by Dean F. E. Turneaure, and "After the War Conditions," by Mr. James Keeley.

Monday, January 15 (No. 956)—Annual meeting of the Hydraulic, Sanitary and Municipal Section. "Modern Sewage Treatment," by Mr. T. Chalkley Hatton, and "The Purification of Sewage in the Presence of Activated Sludge," by Dr. Edward Bartow.

Monday, January 22 (No. 957)—Joint meeting of the Electrical Section with the Chicago Section of the A. I. E. E., being the annual meeting of the Electrical Section. "The Nature of the Power Requirements of the Electrochemical Industry," by Mr. F. A. Lidbury.

Wednesday, January 31 (No. 958)—Joint meeting with the Chicago Section of the A. I. E. E. "Relations of Public Utilities and the Public," by W. W. Freeman.

Monday, February 5 (No. 959)—Regular meeting. "Pitting of Water Turbines and Their Design," by Prof. S. J. Zowski.

Monday, February 5 (No. 960)—Patriotic meeting. Addresses on the Engineer Officers Reserve Corps and the Military Training Camps were made by President Burt, Col. Charles S. Riché, Col. Julius A. Penn, Major Paul B. Malone and Mr. C. C. Saner.

Monday, February 19 (No. 961)—Washington Award Meeting. The subject of the evening was "Engineering in Washington's Time." The following papers were presented: "Surveying," by Ernest McCullough; "Iron and Steel Industry," by James N. Hatch; "Hydraulic, Sanitary and Municipal Engineering," by Charles B. Burdick; "Roads and Pavements," by Arthur N. Johnson, and "Shipbuilding," by John G. Kreer.

Monday, February 26 (No. 962)—Joint meeting of the Electrical Section with the Chicago Section of the A. I. E. E. "The Making of Rates After Valuation," by Mr. W. J. Norton.

Monday, March 5 (No. 963)—"The Preparation of Rock Products," by Mr. Raymond W. Dull.

Monday, March 12 (No. 964)—Meeting of the Bridge and Structural Section. "The C. & N. W. Bridge Over the North Branch of the Chicago River at Deering," by Mr. O. F. Dalstrom, followed by a description of the machinery used to operate the bridge, by Mr. C. H. Norwood.

Monday, March 26 (No. 965)—Joint meeting of the Electrical Section and the Chicago Section of the A. I. E. E. "The Financial Plan of the Report of the Chicago Traction and Subway Commission," by Mr. Bion J. Arnold.

Monday, April 2 (No. 966)—"Landscape Gardening in the Middle West," by Dr. Wilhelm Miller.

Monday, April 16 (No. 967)—Meeting of the Hydraulic, Sanitary and Municipal Section. "American Research Methods," by Mr. Charles H. McDowell.

Monday, April 23 (No. 968)—Joint meeting of the Electrical Section and the Chicago Section of the A. I. E. E. "Economical Industrial Applications of Electricity," by Mr. Norman T. Wilcox.

Monday, April 30 (No. 969)—Meeting of the Bridge and Structural Section. "The Method of Ellipse of Elasticity and Its Application to Continuous Arches on Elastic Piers," by Mr. S. Moreell, Jr.

Monday, May 14 (No. 970)—Meeting of the Bridge and Structural Section. "The Behavior of the Flat Slab Concrete Building in the Quaker Oats Fire at Peterboro, Ont.," by Mr. T. D. Mylrea.

Monday, May 21 (No. 971)—Meeting of the Hydraulic, Sanitary and Municipal Section. "Surveying Methods on the Wilson Avenue Water Tunnel," by Mr. H. W. Clausen.

Monday, May 28 (No. 972)—Joint meeting of the Electrical Section with the Chicago Section of the A. I. E. E. "Electric Waves," by Prof. William S. Franklin.

Monday, June 4 (No. 973)—"Intercepting Sewer Construction in the Northern Part of the Sanitary District of Chicago," by Mr. H. R. Abbott.

Monday, June 11 (No. 974)—Meeting of the Hydraulic, Sanitary and Municipal Section. "Refuse Disposal," by Mr. Rudolph Hering.

Monday, June 18 (No. 975)—Smoker. The meeting was devoted to patriotic speeches and entertainment. Mr. Guy D. Worcester described his experiences with a Canadian battery in France; Mr. Harrison B. Riley explained preparations being made to meet war emergencies and Mr. H. S. Baker, chairman of the Military Committee of the W. S. E., gave an address on "What Western Society Members Are Doing to Serve the U. S."

Monday, September 10 (No. 976)—Regular meeting. "The Monorail as a Method of Transportation and How It Can Be Applied to Chicago," by Mr. F. D. Flint.

Monday, October 1 (No. 977)—Ladies' night. "Homes of Today and Citizens of Tomorrow," by Mr. C. B. Ball.

Monday, October 8 (No. 978)—Regular meeting. The subject for the evening was "Fire Prevention." The following papers were presented: "Building Column Tests," by Mr. William C. Robinson; "Economics of Fire Prevention," by Mr. Frank D. Chase, and "Fire Prevention Work of the

Chicago Fire Department," by Mr. C. W. Hejda. A moving picture entitled "The Unbeliever Convinced," accompanied the last paper presented.

Monday, October 15 (No. 979)—"Construction Features of the Argyle Street Sewer System," by Mr. Herbert E. Hudson.

Monday, October 22 (No. 980)—Joint meeting of the Electrical Section with the Chicago Section of the A. I. E. E. "Engineering Problems of the Signal Corps," by Lieutenant-Colonel L. D. Wildman. This address was followed by a moving picture entitled "Who Leads the National Army."

Monday, November 5 (No. 981)—Regular meeting. "Lumber and Lumbering from an Engineering Standpoint," by Mr. O. N. P. Goss.

Monday, November 12 (No. 982)—Meeting of the Bridge and Structural Section. "The Resistance of a Group of Piles," by Prof. H. M. Westergaard. There was also presented a moving picture entitled "Shifting of Foundations of High Buildings."

Monday, November 19 (No. 983)—Meeting of the Mechanical Section. "Manufacture and Distribution of Gases," by Mr. C. W. Bradley.

Monday, November 26 (No. 984)—Joint meeting of the Electrical Section with the Chicago Section of the A. I. E. E. "Engineering Data Necessary for an Electric Rate Determination," by Mr. Bert H. Peck.

Monday, December 3 (No. 985)—Regular meeting. "Construction of Cantonment at Camp Grant," by Mr. Charles B. Burdick; "Army Cantonment Construction at Camp Meade, Maryland," by Prof. N. B. Garver; "Heating, Cooking and Laundry Equipment of the National Army Cantonments," by Mr. A. C. Willard, and "The Resistance of a Group of Piles," by Prof. H. M. Westergaard.

Monday, December 10 (No. 986)—General meeting of the Society with ladies invited. "What the War News Means," by Mr. S. J. Duncan-Clark, and a two-reel moving picture, "Over Here."

Monday, December 17 (No. 987)—"What the War Means to the Engineer," by Mr. Edward J. Mehren.

Thursday, December 27 (No. 988)—Joint luncheon of the Electrical Section with the Chicago Section A. I. E. E., as guests of the Electric Club-Jovian League of Chicago. "The Relation of Science and Engineering to the War," by Major Robert A. Millikan (read by Prof. Harvey B. Lemon).

Respectfully submitted,

EDGAR S. NETHERCUT, Secretary.

Report of Chanute Medal Awards

Mr. H. J. Burt, President, Western Society of Engineers:

Dear Sir: The undersigned, as a committee to make the award of the Chanute Medals for papers presented to the Society for the year 1916, beg to report as follows:

We unanimously recommend to the Board of Direction that two Chanute Medals, and two only, be awarded for papers presented in 1916, namely, to Capt. H. B. Sauerman, M.W.S.E., for a paper in general engineering entitled "Fortification," and to Clinton B. Stewart, M.W.S.E., for a paper in Civil Engineering entitled "Investigation of Flood Flow on the Wisconsin River at Merrill, Wis."

Respectfully submitted,

P. B. WOODWORTH,
JOHN ERIKSON,
E. E. R. TRATMAN,

Committee to Award Chanute Medals.

Report of the Judges of Election, Western Society of Engineers, January 24, 1918

The undersigned Judges of Election, having canvassed the ballots cast for officers of the Western Society of Engineers for the year 1918, have the honor to report as follows:

Total number of votes cast	344
Total number of ballots rejected as irregular	5
Total number rejected as not qualified to vote, account non-payment of dues	7
Total number of ballots counted	332
For President:	
Chas. B. Burdick	247
D. W. Roper	80
For First Vice-President:	
James N. Hatch	312
For Second Vice-President:	
Kempster B. Miller	307
For Third Vice-President:	
A. S. Baldwin	233
W. S. Lacher	90
For Treasurer:	
C. R. Dart	316
For Trustee for Three Years:	
W. W. DeBerard	200
Carl A. Keller	124

Respectfully submitted,

John W. Page,
C. M. Denise,
R. F. Schuchardt.
Judges of Election.

Proceedings of the Annual Meeting and Dinner, January 24, 1918

Toastmaster Llewellyn: Now if I were permitted a few intimate references, I should say that Mr. Butler is a man of action; he has eight children—including two pairs of twins. And I am given to understand that there is a family tradition which sets aside St. Patrick's Day for purposes of this kind. (Applause.) Mr. Butler is entitled to a service flag of three stars, evidencing three of his boys at the front. He is a Regent of the University of Minnesota and President of the State Bar Association.

Upon one occasion golf was prescribed for him to save him from an early grave. The M. D. who looked him over pronounced him the finest physical specimen that he had even seen, and since that day no man has ever mentioned golf to Mr. Butler. It is a foolish pastime with him.

Those of us who are familiar with his career will understand that his favorite dish is bleached flour, of which he is so fond that he once disposed of several cases with the utmost relish quite successfully. Meat, however, does not digest as readily with Mr. Butler.

His beginnings were quite orthodox, in that he spent his early days

on the farm, to which one day as an agriculturist, he expects to return. He once worked on a ranch in a severely irrigated district where moisture is at a premium, and there was a day when there was a little rain which fell, but he sought no shelter within the house. But this was remarked at the supper table, and he said, "Oh, I don't mind a little thing like that. A little dew of that kind won't hurt me." But the rancher said, "Nothing doing; next time you come in; I want the rain to fall all on the land."

Gentlemen, we have been living in the age of complacency. There are some who have passed through and beyond, while many still remain in the succeeding age, which is the era of criticism and raillery, but there are many who have already emerged into that which—and we be not traitors to our destiny, soon must instantly be the age of universal responsibility.

Our guest has always been an apostle of serious and dynamic responsibility. It is in this atmosphere that he has achieved his success and his distinction, and it is at a moment of this kind, with peculiar satisfaction, that I avail myself of the honor of introducing to you Mr. Pierce Butler of St. Paul, General Counsel of the Western Group of the President's Conference Committee on the Federal Valuation of Railroads, Mr. Butler. (Applause.)

Toastmaster Llewellyn: Gentlemen, if Mr. Butler can remain with us long enough, I believe that we can not express our sentiments toward him and towards his speech and towards the features which he has enunciated in his closing remarks in any way as well as we can by joining together in singing a song which has been composed for this occasion by one of our own members, Mr. Andrees Allen, to the tune of "Onward, Christian Soldiers," No. 11, and I would suggest that while Mr. Butler is still here we arise and be led by Mr. Hyde, singing with enthusiasm and with perfect understanding this No. 11 in the book of songs.

Gentlemen, this brings us to the business session of our meeting, which will be led by Mr. Burt, President of the Western Society. (Applause.)

Mr. Burt assumes the office of chairman.

The President: The first order of business will be a report from our Secretary, Mr. Edgar S. Nethercut. (Applause.)

The President: The report of the Secretary will be spread upon the records of the society.

One of the greatest members of this society was Octave Chanute. One of the greatest men of his profession was he. To him is due much of the credit for the development of aviation. It was on his work that the work of the Wright Bros. was founded. He did a special service to this society in making to it a gift, the proceeds from which from year to year are used in purchasing medals to be presented to those of our members who present the most creditable papers during the proceding year on engineering subjects. For the year 1916 the report of the Special Committee appointed for that purpose is as follows:

Capt. H. B. Sauerman and Mr. C. B. Stewart come forward and are presented with the Octave Chanute Medals.

At the request of Mr. Llewellyn a selection is presented by the Glee Club.

The President: Members of the Western Society of Engineers: It is one purpose of my address tonight to bring before you some idea of the achievements of this society, and to present a vision of still greater usefulness, so that you may have a better appreciation of its past work and an ambition for future development.

(Mr. Burt's address is printed on page 55.)

Toastmaster Llewellyn: Gentlemen, I hope it will be possible for us to remain largely to the close of our proceedings, which will not be very much prolonged. I have Mr. Burt's permission, as I said, to announce the music, but because so far I haven't had very much of a chance, and because it serves as a fitting introduction to our next number, I am going to ask his permission to tell a story. It is concerning British Colonization, and

it is of the boy who was the son of a noted American Historian who was writing a composition on that subject, and he said: "Africa is a British Colony. And I will tell you how they do it. They first get a missionary and send him over there, and when the missionary has found a nice fertile tract of land he gathers all the people together and says, 'Let us pray,' and when all the eyes are shut up goes the British Flag."

Now I don't know what the policy of Britain is going to be after the war, but I do know that there is a duty incumbent upon us here in America to keep the home fires burning. We will sing at this time No. 13, "Keep the Home Fires Burning," to be followed immediately by No. 17, "Over There."

I want to say I believe Mr. Burt will very shortly announce the results of the election and will introduce the new officers of the society and the address of the President will be read. I want to say that immediately after the reading of the address the new President, and without any announcements of any kind, let us give him our Good Morning, Mr. Zip Zip Zip, and let us all join together in giving him this Good Morning.

Mr. Burt: I now want to introduce to you the men whom you have charged with the care of your society during the coming year, and I want to introduce to them at the same time the men who are going to help them do it, and that is all of you.

President, Mr. Charles B. Burdick. (Applause.)

First Vice-President, Mr. James N. Hatch. (Applause.)

Second Vice-President, Mr. Kempster B. Miller. (Applause.)

Third Vice-President, M. A. S. Baldwin. (Applause.)

Treasurer, Mr. C. R. Dart. (Applause.)

Mr. George C. D. Lenth, Trustee until 1919.

Mr. O. F. Dalstrom, Trustee until 1920.

Mr. W. W. DeBerard, Trustee until 1921.

Mr. William B. Jackson, Past President, serving on the Board until 1919.

Mr. B. E. Grant, Past President, serving until 1920.

Mr. E. N. Kake, a member of the Board, as Chairman of the Electrical Section.

Mr. J. W. Lowell, Jr., as Chairman of the Bridge and Structural Section.

Mr. H. E. Hudson, as Chairman of the Hydraulic, Sanitary and Municipal Section.

Prof. G. F. Gebhardt, as Chairman of the Mechanical Section.

Mr. Burdick has been assigned to duty as Supervision Engineer of Construction for work in Porto Rico, and on that account he is not able to be here, and he will be absent for the next three or four months. Mr. Hatch will serve as his proxy and will now deliver to you Mr. Burdick's address.

Mr. Hatch: Mr. Chairman and Gentlemen: In assuming this position I am reminded of a lecture I heard by Sam Jones once. He was explaining the efforts he made to adapt his speech to the conditions under which they were to be given, and he said he thought he had been fairly successful in all the attempts. For instance, at one time he was preaching a sermon in the South where there were a good many colored people in attendance, and he attempted to assume a position that would please the colored people, and he said he thought he was fairly successful, for after the sermon one of the Negro women came up to him—one of those great big good-natured women that would weigh two hundred pounds dressed—and she said, "Mr. Jones, I sure do like your preaching; you sure do preach more like a Nigger than any White man I ever heard before in my life." (Laughter.)

Now I shall attempt to make this sound as much like a real President as I can. This was written by Mr. Burdick and so I don't take any responsibility for what it may contain.

(Mr. Burdick's address is printed on page 64.)

Mr. W. H. Finley: I feel that this dinner shouldn't close without some expression of appreciation from the members to our retiring Presi-

dent for the able and dignified way in which he has conducted the affairs of the society during his term of office, and also for his very inspiring address tonight. I know you were all highly edified, as I was, and I, therefore, move a vote of thanks to the retiring President, Mr. Burt.

Mr. Isham Randolph: I want to say that I have been very much interested tonight in the talk on the subject of Railroad Valuation by Mr. Butler. To a great many of us the chief good in this would seem to be that it came in at a time when there was a great depression, and it afforded employment for a great many of our good men. But that is past now, and we certainly owe a vote of thanks to the gentleman who has instructed us on this line so wonderfully tonight and gave us so much information. It is true he left us, as I think he was, very much in a fog as to what is to be the final outcome of it, but it was an exceedingly interesting discourse, and I move a vote of thanks be extended to Mr. Butler.

The Chairman: This motion is duly seconded and unanimously carried. I take it for granted that that suggestion carries with it the suggestion that the motion be spread through the minutes and sent to all the members.

Mr. Randolph: That is the correct assumption.

Now Mr. Burt informs me that that is the end of the business meeting, but there is mentioned on the program the possibility of a song fest following our more formal proceedings, and as we have a number of good songs left, there is no reason why we can't carry out that suggestion.

Members begin to disperse and meeting is declared adjourned at 11:25 P. M.

EDGAR S. NETHERCUT, Secretary.

BOOK REVIEWS

Railway Estimates, Design, Quantities and Costs, by F. Lavis. 608 pages 6 by 9 inches, about a hundred illustrations, numerous tables and plates. Bound in cloth. Published by McGraw-Hill Book Company, Inc., New York. Price, $5.00.

Constructing engineers have use for a great deal of data and information, that they may report on the value, or estimate the probable cost of proposed railroads; to estimate the value of existing lines; to design the general features of a proposed railway or modify an existing one, or to determine the utility or value of the features which affect the value or cost of railways as transportation equipment.

"Railway Estimates" aims to give the engineer this information, or rather to supplement such information as the engineer may have. A vast amount of data is arranged for easy reference or careful study, not only to the established man, but to the student of engineering who is specializing on railroad work. It gives facts and figures regarding costs on railroads in many countries and built and operated under widely varying conditions.

Each of the various items of Preliminary Estimates, General Costs, Earthworks, Tunnels, Masonry, Arches, Culverts, Bridges, Track, Buildings, Shops, Rolling Stock, etc., is discussed in detail, making the book exceedingly valuable for reference in any line of railway work. C. A. M.

Use of Water in Irrigation. By Samuel Fortier. Cloth, 6 by 8, 318 pages with illustration. McGraw-Hill Book Company, New York. Price, $2.00.

This is the second edition, revised and enlarged, of this well-known book. The principal additions are in the articles on Irrigation in Foreign Lands and Sewage Irrigation. The first edition, reviewed in the Journal in January, 1915, contained a good description of American practice and the addition of foreign practice forms a valuable supplement to the work. The uses of irrigation in eighteen foreign lands are described.

The volume is one of the Agricultural Series and it is evident that the author has made use of the access to governmental statistics, the greater part of these being of the date 1910. Realizing the great progress that has been made since that time, the reader is led to wonder what the comparisons would show if brought down to date.

As an engineer, the author discusses the flow and measurement of water through weirs and channels. Several tables are given and many of these should be of value in the field of hydraulics aside from their particular application to irrigation problems.

The engineer who reads this book is impressed with the great amount of information set forth for the use of the prospective farmer of irrigated lands. Classifications of soils and crops and proper planting conditions are discussed in detail. There are many useful hints as to possible pitfalls for the unwary purchasers. Many legal points in the steps necessary for purchase, maintenance and protection of titles to irrigated lands and water rights are covered. In this respect, the book is particularly of value to the engineer who is new in the study of irrigation, and to the farmer of irrigated lands.

Nine different methods of applying water to the soil are described. There are many ingenious devices and methods included among these.

While the value of the volume is greatest to the irrigation farmer, it is an educational and instructive addition to an engineering library.—H. E. H.

United States Artillery Ammunition. By Ethan Vaill, Managing Editor of the *American Machinist*, 98 pages, 9 by 11, cloth binding. Published by the McGraw-Hill Book Company, New York. Price, $2.00.

This book is compiled for the use of shopmen, engineers, manufacturers, and covers steps in the manufacture of 3-inch to 6-inch shells and cartridge

cases used in both the army and navy. It describes the operation of machines and men in the fabrication of the various pieces, including the final protective coatings. A liberal use of photographs and well executed perspective drawings adds materially to the interest of the book .

The reader is impressed by the great predominance of lathe work in this class of manufacture. The description of the various lathe operations shows the progress made in this class of work. Aside from the use of lathes, the drill press is the only machine that is greatly used.

The time studies and details of operations recorded in this book are well arranged and should prove of great value to the manufacturer or engineer interested in this field. The work is covered in a most thorough manner and many of the operations are interesting and unusual. The engineer busily at work will find that time given to reading this book is well spent. Just at present it has a special timely interest, while the methods of handling metal and treating metal surfaces should be of value in other mechanical fields. H. E. H.

United States Rifles and Machine Guns. By Fred H. Colvin and Ethan Vaill, Associate Editors of the *American Machinist*. 339 pages, 9 by 12, bound in cloth. Published by the McGraw-Hill Book Company. Price, $3.00 net.

In the preface, the authors explain the purpose and uses of this work. It is one of a series undertaken to assist manufacturers having large contracts with the Government for the manufacture of Ordnance Supplies. This volume has to do with the operations in the fabrication of the Springfields, Model 1903, service rifle.

The title of the book might lead one to expect a greater amount of detail concerning the other arms than is given. The descriptions are interestingly written and have a special educational value at this time. The U. S. Automatic Machine Rifle, Cal. 30, Model 1909; the Lewis Machine Gun and the Vickers Machine Gun, Model 1915, are three types of machine guns described. Drawings and photographs enlighten the reader on these types of guns, and together with the written description, afford a real education in machine gun design and operation. The short description of the Modified Enfield Rifle, now known as the U. S. Model 1917, shows the similarity between this gun and the Springfield Model 1903. The contrasting points between these two rifles is also set forth, but the reader or student will feel that the description is all too short.

The historical data and photographs showing the evolution of the American Military Rifle form a very interesting addition to such a technical volume. The story there told is of value to a real "gun enthusiast" or patriot. H. E. H.

PROCEEDINGS OF THE SOCIETY

Meeting No. 989, January 7, 1918.

This was a general meeting of the Society and was attended by forty-five members and guests. Mr. D. W. Roper, First Vice-President, presided. The subject of the evening was "Unification of Local Governments and City Manager Plan for City of Chicago." The speaker, Mr. George C. Sikes of the Chicago Bureau of Public Efficiency, delivered an address outlining the work of the Bureau of Public Efficiency. The subject was discussed by Messrs. C. D. Hill, Harold Almert, C. H. Cenfield, H. W. Clausen, C. A. Keller, C. H. Norwood and R. F. Schuchardt.

The meeting adjourned at 10:15 P. M.

ANNUAL MEETING OF THE SOCIETY

Thursday, January 9, 1918.

The meeting was called to order at 3:20 P. M., by Mr. D. W. Roper, Vice-President. There were present the Chairman, Secretary and three other members. The Chair announced that there being no quorum a motion to adjourn to a subsequent date was in order. It was moved by Mr. Copeland and seconded by Mr. Abbott that the meeting be adjourned to January 24th, 1918, at 8:30 at the Congress Hotel, CARRIED.

Meeting No. 990, Thursday, January 14, 1918.

This meeting was held as a regular meeting of the American Institute of Electrical Engineers being their 336th meeting. The members of the Western Society of Engineers were guests. There were present sixty-five members and guests. The meting was called to order by Mr. R. F. Schuchardt. The subject of the evening, "The Effects of War Conditions on the Cost and Quality of Electric Service," was presented by Mr. William B. Jackson, the paper being prepared by Mr. Jackson and Mr. Lynn S. Goodman. This being the first meeting of the Electrical Section of the year, the regular order of business was the election of officers of the Section for the year 1918. The report of the Nominating Committee was presented. There being no further nominations, on motion duly made and seconded the Secretary cast the ballot of the Section in favor of the nominees, as follows:

Chairman	E. N. Lake
Vice-Chairman	J. R. Cravath
Member of Executive Committee to fill vacancy	Chas. H. Norwood
Member of Executive Committee for three years	Ernest Lunn
Member of Executive Committee for two years	C. A. Keller

The meeting adjourned at 10:00 P. M.

Meeting No. 991, January 22, 1918.

This was a meeting of the Hydraulic, Sanitary & Municipal Section. Mr. H. E. Hudson, Chairman of the Section presided. There were present thirty members and guests. The special order of business was the adoption of the proposed new rules for the Section and the election of an Executive Committee for the year 1918. The result of the election is as follows:

Chairman	H. E. Hudson
Vice-Chairman	Linn White
Directors of Executive Committee	Don E. Marsh Wm. Artingstall O. C. Simonds

Rules of the Section.

The Secretary read the rules of the Section having been previously read to the Section. Amendments were offered to Sections 2, 4, 6 and 7. These amendments were adopted and the rules as amended, were thereupon adopted.

The subject of the evening was "Analysis of the Traffic Count in Downtown Chicago." The paper was presented by Mr. George C. D. Lenth, Assistant Chief Engineer of the Board of Local Improvements, Chicago,

and this was illustrated by numerous slides showing the method of making the traffic count and tabulation of the results.

The paper was discussed by Messrs. Ray Seeley, T. Lovel D. Hadwen, O. F. Dalstrom, W. W. DeBerard, A. J. Shafmayer and H. V. Stephenson.

The meeting adjourned at 10:30 P. M.

Meeting No. 992, Thursday, January 24, 1918.

The Annual Dinner of the Society and the 48th Annual Meeting were held Thursday evening, January 24, 1918, in the Gold Room of the Congress Hotel. The meeting was attended by 225 members and guests. During the dinner music was furnished by the Universal Glee Club with Mr. J. H. Libberton, leader. The community singing was lead by Mr. Herbert Hyde and proved to be a very successful part of the program. This music was accompanied by a special orchestra. Mr. Andrews Allen contributed an original song entitled, "Onward Now Americans" which was sung to the tune of Onward Christian Soldiers. Mr. F. J. Llewellyn, Chairman of the Annual Dinner Committee, presided as Master of Ceremonies.

The speaker of the evening was Mr. Pierce Butler, Valuation Counsel, Western Group of Railroads. Mr. Henry J. Burt, Retiring President, presented his annual address and reported the award of the Chanute Medals to Capt. Henry B. Sauerman for a paper in general engineering entitled, "Fortification," and to Mr. Clinton B. Stewart for a paper in civil engineering entitled, "Investigation of Flood Flow on the Wisconsin River at Merrill, Wisconsin," and awarded the medals. Mr. Burt also announced the result of the election of officers for the ensuing year.

In the absence of President-Elect Burdick, his inaugural address was read by Mr. James N. Hatch, First Vice-President.

The Secretary presented abstracts from his annual report which are published in the proceedings.

At this dinner the service flag of the Western Society of Engineers, containing ninety-one stars, was displayed.

Meeting No. 993, Tuesday, January 29, 1918.

This was a meeting of the Bridge and Structural Section and was held on Tuesday evening on account of the government requirements of fuelless Mondays. Mr. J. W. Lowell Jr., Chairman of the Bridge and Structural Section, presided.

The special order of business was the adoption of the rules of the Section and the election of the Executive Committee for the year 1918. The Secretary read the rules as previously read to the Section. Amendments were proposed to Sections 2, 4 and 7, and adopted. The rules as amended were then adopted, subject to the approval of the Board of Direction.

Election of Officers

After the nominations of officers, on motion duly made and seconded the following were declared elected:

Chairman	J. W. Lowell, Jr.
Vice-Chairman	G. A. Haggander
Director, 2 year	Lee Jutton
Director, 1 year	W. L. Cowles
Director, 1 year to fill vacancy	Prof. M. B. Wells.

The address of the evening was made by Lieut. Lee Hammond, U. S. N. R., in charge of the Flying School at the Great Lakes Naval Training Station on the subject of "The Aeroplane and Its Use as a War Machine." This address was very instructive, describing fully the construction and uses of the aeroplane in war. The subject was discussed by Mr. Charles Dickenson, President, and Mr. James Stephens, Vice-President of the Aero Club of Illinois.

The meeting was attended by 120 members and guests and adjourned at 10:15 P. M.

Edgar S. Nethercut,
Secretary.

Journal of the

Western Society of Engineers

VOL. XXIII. FEBRUARY, 1918 No. 2.

ANALYSIS OF THE TRAFFIC COUNT IN DOWNTOWN CHICAGO

By George C. D. Lenth, M. W. S. E.*

Presented January 22, 1918.

Some years ago the Commercial Club of Chicago, through the genius of Daniel Hudson Burnham, formulated and gave to the people of Chicago a comprehensive plan for the future development of the City.

The Burnham Plan contemplated the opening and widening of certain thoroughfares such as Michigan Avenue, Twelfth Street and Ogden Avenue, and the development and beautification of the shores of Lake Michigan for the benefit of the people. The elimination of the river as the natural line of division between the three parts of Chicago was to be accomplished by the opening of wide thoroughfares with adequate bridges across the river. The lake shore within the heart of Chicago was occupied by railroads and was used in part as a city dump. Instead of the lake shore being the great natural breathing place for the people it was a place to be shunned and not readily accessible. The view of the lake was obscured by the smoke of puffing locomotives and from the mouth of the river on the north to 51st Street on the south, a distance of approximately six miles, the shore was private property. Through the activity of the Plan Commission the Association of Commerce and public spirited citizens the shores of Lake Michigan have been restored to the people.

For more than a score of years the necessity of better traffic facilities in Michigan Avenue was recognized. In 1905 the Board of Local Improvements, through its Engineer, C. D. Hill, M. W. S. E., made the first detailed plan for the widening of Michigan Avenue. This plan, after its submission to the people of Chicago, caused a great deal of discussion and after eight years of study in conjunction with the Plan Commission, the Board of Local Improvements developed the present plan, now no longer a dream, but approaching a reality. All of the legal hurdles which an improve-

*Assistant Chief Engineer of Sewers, Board of Local Improvement, Chicago.

ment such as this must overcome when built by special assessment have been successfully surmounted. The actual construction and the demolition of buildings will be under way within the next four months.

This study of traffic was brought about by and in consequence of the proposed widening of one of the most congested thoroughfares in the heart of Chicago. Michigan Avenue, from Randolph Street to the Chicago River, is at present a 66 ft. thoroughfare, with a 38 ft. roadway. On the north side of the river slightly east of Michigan Avenue extended is Pine Street, which is a 66 ft. thoroughfare with a 38 ft. roadway. It is proposed to widen Michigan Avenue by the addition of 61½ ft. on the east and Pine Street by the addition of 75 ft. on the west, and to connect the two parts with a bridge across the Chicago River. The total cost of the proposed improvement is $7,500,000.00, $5,000,000.00 of which is the value of the building and land taken, and $2,500,000.00 of which is the value of the bridge, approaches, etc. In order to fully appreciate the traffic problem and its solution, the speaker will give a brief description of the proposed Michigan Avenue improvement, leaving the details as a subject of a future paper.

The plan of the improvement of Michigan Avenue, starting at the north curb line of East Randolph Street, extends northward along Michigan Avenue as widened to the east and over the Chicago River, and thence over private property and along Pine Street as widened to the west to the center line of East Chicago Avenue, together with a connecting bridge across the Chicago River. See Figure 1.

The improvement consists of a two level thoroughfare comprising an upper deck extending the entire distance between the points above indicated, and supported between East Lake Street and East Grand Avenue upon an elevated structure of steel and concrete and a lower level extending from the south line of East Lake Street to the north line of East Grand Avenue, together with approaches to said thoroughfare along intersecting streets and alleys. That part of the thoroughfare extending across the river consists of a double decked bascule bridge, the upper deck of which connects the portions of the upper level of said thoroughfare lying north and south of the river, and the lower deck of which connects the portions of the lower level of the thoroughfare lying north and south of the river. The improvement includes filling, excavation, retaining walls, abutment walls, bridge houses, curbing, pavements, sidewalks, stairways, electric lighting equipment, and other work requisite to make a complete thoroughfare and bridge. The thoroughfare from the north curb line of Randolph Street to a plaza located on the south side of the river is 127½ feet in width. The upper deck of the bridge is 90 feet in width, and the lower deck of the bridge is 60 feet in width. The bridge has a clear span of 220 feet between abutments, and 256 feet between the center lines of the trunnions. The width of the thoroughfare between the north plaza, which is

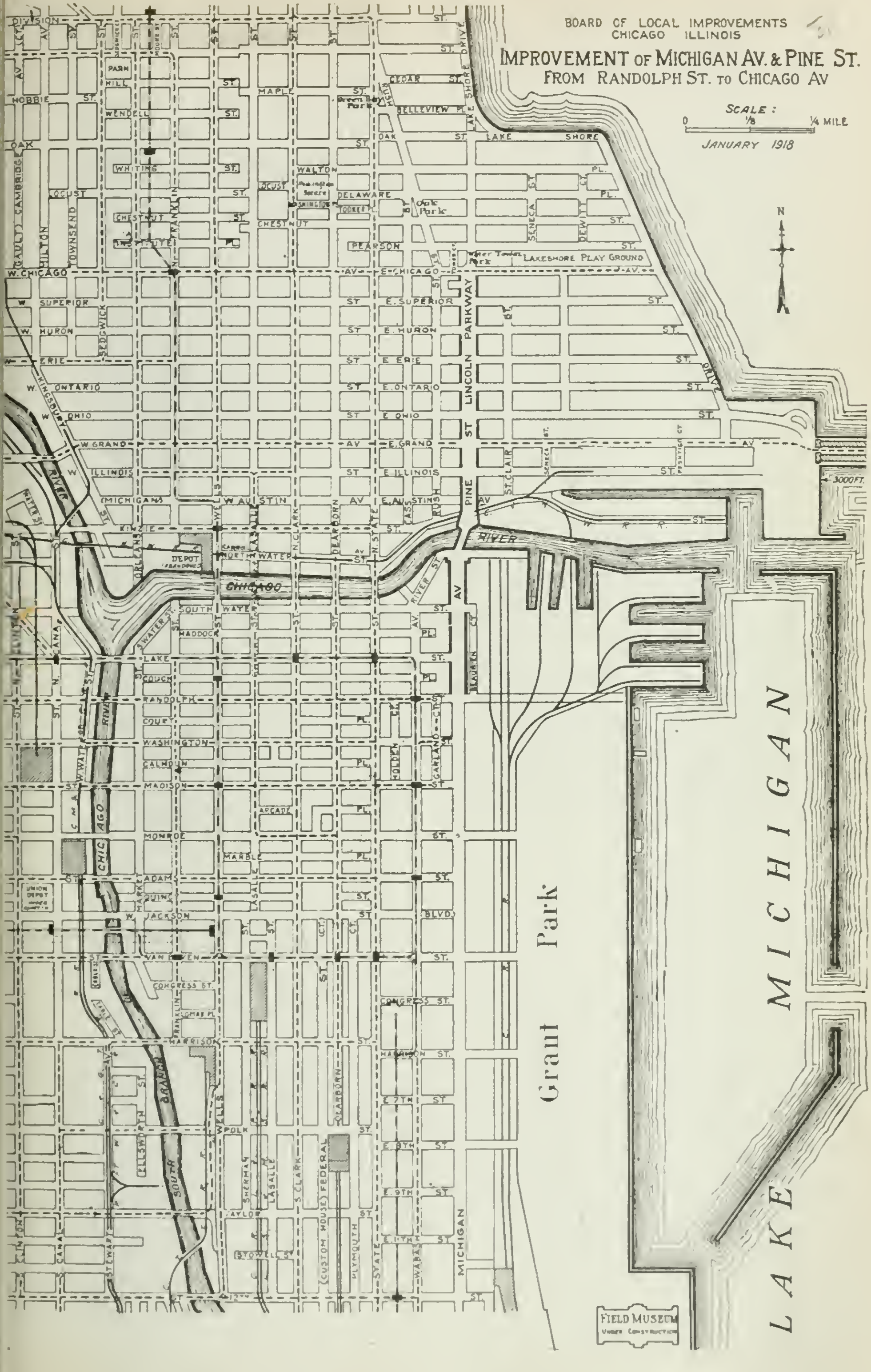
BOARD OF LOCAL IMPROVEMENTS
CHICAGO ILLINOIS
IMPROVEMENT OF MICHIGAN AV. & PINE ST.
FROM RANDOLPH ST. TO CHICAGO AV
SCALE:
0 1/8 1/4 MILE
JANUARY 1918
N
LAKE SHORE DRIVE
LINCOLN PARKWAY
PINE ST
CHICAGO RIVER
SOUTH BRANCH
Grant Park
LAKE MICHIGAN
FIELD MUSEUM
UNDER CONSTRUCTION
3000 FT.

Figure 1

north of and adjoining the bridge, and the northern terminus of the improvement, is 141 feet. From Randolph Street to the south line of the south plaza the west line of the thoroughfare coincides with the present west line of North Michigan Avenue and from the north line of the north plaza to Chicago Avenue the east line of the thoroughfare coincides with the east line of Pine Street.

The grade of the upper level, as will be noted on the profile shown on Figure 2, rises gradually from the elevation of 19 feet at Lake Street, thence to an elevation of 26 feet at South Water Street, thence to a maximum elevation of 37 feet on the bridge at the river, thence descending gradually to an elevation of 24 feet at Grand Avenue, and thence to the present elevation of 13 feet at Ontario Street. The grade of Lake Street rises from the present elevation at Wabash Avenue to the proposed elevation of 19 feet at Michigan Avenue, and the grade of Ohio Street rises gradually from Rush Street on the west and St. Clair Street on the east to the proposed elevation of 16 feet at Pine Street. Between Lake Street and Ohio Street there will be no connection between the upper roadway of the thoroughfare and the intersecting streets and alleys except by stairways. The lower roadway will be connected with Lake Street to the east of Michigan Avenue, and to South Water Street, River Street, North Water Street, Austin Avenue, Illinois Street and Grand Avenue. The elevation of the lower roadway will be depressed to provide the necessary head room below the upper level at Lake Street, South Water Street and Grand Avenue. The lower roadway will be at the present elevation of the existing streets at River Street, North Water Street, Austin Avenue and Illinois Street. This lower roadway will be continuous from Lake Street to and across the lower deck of the bascule bridge, and thence north to Grand Avenue. The intersection of the lower roadway on Grand Avenue will be depressed five feet to an elevation of 8 feet above datum, which is sufficient to permit the passage of street cars along Grand Avenue.

The upper level south of the south plaza will have a roadway 75 feet in width. The west sidewalk will be 27½ feet in width, and the east sidewalk 25 feet in width. These widths correspond to the present roadway and sidewalks of Michigan Avenue south of Randolph Street. Crossing the river the upper deck of the bridge will have two roadways 27 feet in width with overhanging sidewalks on each side of the bridge 15 feet in width, with a platform 5 feet in width serving as a safety isle between the roadways. Under this platform are the tops of the center trusses of the bridge and the joint between the trusses. North of the north plaza and south of Ohio Street the roadway will be 80 feet wide with two sidewalks, each 30½ feet in width. North of Ohio Street the roadway will continue 80 feet in width, and on each side of the street there will be sidewalks 12 feet in width with grass plats 18 feet in width between the sidewalks and the curb. The roadway of the upper level is to be paved with asphalt from Randolph Street to Chicago Avenue. The sidewalks will be of concrete with large areas of sidewalk glass

to illuminate the lower level. The streets leading to Michigan Avenue will be repaved and refurnished with new sidewalks from Wabash Avenue to the new thoroughfare. The pavement on Michigan Avenue between Randolph Street and Lake Street will be laid on filling between curb walls and a similar construction will be provided in the thoroughfare from Grand Avenue to Ohio Street. The columns supporting the upper level from Lake Street to Grand Avenue will be spaced as far apart as possible, consistent with good design, so as to cause the least possible interference with traffic on the lower level. The lower level roadways will be paved with granite blocks except the lower deck of the bridge which will be

Courtesy Chicago Tribune.

Figure 5. Traffic on Michigan Avenue.

paved with creosoted wooden blocks. The lower deck of the bridge will be provided with two roadways each 18 feet in width, with two sidewalks, each 5 feet in width.

A more complete description of this improvement is contained in the ordinance which is published in the Journal of Council Proceedings of the City of Chicago, under the date of March 9th, 1914, to which the reader is referred.

Michigan Avenue south of Randolph Street is under the jurisdiction of the South Park Commissioners who control this thoroughfare as a boulevard. There is, therefore, no commercial traffic permitted on this street except that necessary to serve the abutting property. The width of the roadway on Michigan Avenue south of Randolph Street is 75 ft. and at the present time, north of Randolph Street is 38 feet, so that it is apparent that at Randolph Street

the diminution of width of roadway from 75 feet to 38 feet acts as a throttle, causes congestion and backs up the traffic for a considerable distance south of Randolph Street. See Figure 5. The throttling becomes more apparent when one considers that there are leading into Michigan Avenue from the central business district south of Randolph Street several important thoroughfares. Twelfth Street on the extreme south has at the present time between Michigan Avenue and State Street a 30 foot roadway, and will have within the course of the year a roadway 84 feet in width.

At this point it may not be amiss to call attention to this improvement of Twelfth Street, one of the great arteries of Burnham's Chicago Plan now a partly accomplished fact. Twelfth Street has been widened from Michigan Avenue to Ashland Avenue, a distance of 2¼ miles, by the addition of 42 feet on the south, thus making it a thoroughfare 108 feet in width. During the past year and a half great progress has been made. The city has successfully obtained title to the land which was taken at a cost of $3,056,000.00; has caused 500 buildings to be either moved back or razed; has laid on the land taken a new concrete sidewalk 15 feet in width at a cost of $110,000.00; caused the relocation of three miles of street railroad track at a cost of $500,000.00; has laid 1½ miles of new granite block pavement, 78 feet in width, at a cost of $400,000.00, and is about to start on the construction of the viaduct and bridge between Canal Street and State Street at an estimated cost of $1,-100.00.

Twelfth Street extends from Michigan Avenue to the center of the densely populated west side and will, undoubtedly, bring a considerable increase in traffic from the west side to the central business district by the way of Michigan Avenue. In addition, attention is called to Van Buren Street, Jackson Blvd., Adams Street and Monroe Street, each with a 38 foot roadway, and Madison Street, Washington Street and Randolph Street, each with a 48 foot roadway, with Michigan Avenue as their eastern terminus and each of which adds to the congestion of traffic in Michigan Avenue.

The effect on traffic, such as autos and other vehicles, by the proposed opening or widening of a thoroughfare such as Michigan Avenue, especially where the accessibility of the property adjacent is affected, is of great importance. When the widening of Michigan Avenue was contemplated one of the most important elements in determining the benefits and in determining whether such an improvement was local or general in its character, was traffic. The primary object of opening or widening a thoroughfare is to increase traffic facilities, which means an increase in accessibility.

The movements and volume of traffic upon Michigan Avenue as opened and widened, not only affects the thoroughfare itself, but materially affects the traffic in the cross streets, the streets at the termini of the improvement and even various parts of contiguous territory.

In order to study fully all phases and angles of the traffic problem and its effect upon the widening of Michigan Avenue, the following were commissioned to study traffic:

Richard S. Folsom, Formerly Corporation Counsel.
Harry Goldstine, Real Estate Expert.
Fredk. K. Root, Real Estate Expert.
Henry Goetz, Traffic Expert.

The Commission was assisted by the governmental bodies having jurisdiction of the traffic approaching the proposed improvement. The Police departments of the city and the Park Boards co-operated on all occasions. The Park Boards have jurisdiction of the boulevards and the Chicago River is the dividing line of their respective districts. The Commission conferred with the executives of the Chicago Plan Commission which had heretofore made traffic studies and had collected considerable data on traffic. Almost all of the traffic data and counts which were available were incomplete and obsolete, and the information decidedly meager, so that very little reliance could be placed upon them. The Commission finally decided that it was necessary to make an independent and comprehensive study of traffic conditions affecting the Michigan Avenue improvement. The fundamental purpose of this count was to show what effect the traffic across Rush Street Bridge had upon the central business district of Chicago, and what effect the increased facilities by the widening of Michigan Avenue and the building of a double decked street had or would have upon traffic. In order that there be no confusion in terms the words "central business district" and "loop" are to be regarded synonymous.

One of the first points decided upon was the definition or the classification of traffic. The term "automobile traffic," used in this paper is used to designate the traffic of a self propelled machine that carries passengers, entirely distinct from a vehicle carrying freight. All other traffic is classified as commercial traffic, namely, those vehicles, either self propelled or horse drawn, which were used to carry freight, etc.

It was decided to count all traffic vehicles which came in to the central business district of Chicago which is bounded on the south by 12th Street, on the west and north by the Chicago River, and on the east by Lake Michigan.

The gateways to this district on the south are six in number:

Michigan Avenue and 12th Street
Wabash Avenue and 12th Street
Indiana Av. and 12th Street
State St. and 11th St.
Clark St. and Taylor St.
Fifth Av. and Taylor St.

On the west are nine in number:

Randolph St. Bridge
Washington St. Bridge

Madison St. Bridge
Adams St. Bridge
Jackson Blvd. Bridge
Van Buren St. Bridge
Harrison St. Bridge
Polk St. Bridge
Lake St. Bridge (not open for traffic)

On the north are five in number:

Rush St. Bridge
State St. Bridge
Dearborn St. Bridge
Clark St. Bridge
Wells St. Bridge

making a total of nineteen avenues of approach.

It was decided in the count that a record should be made of each and every vehicle entering this district, and that each vehicle entering this district must be accounted for, either by leaving the ditsrict during the hours of observation or be located somewhere within this district. There was virtually thrown around the central business district a Chinese wall and within it a system rivaling that of German espionage was placed on all vehicles entering that district for a period of several days.

FIRST TRAFFIC COUNT

June 21, 22, 23, 24, 26, 27, 1916.
7:00 A.M. to 7:00 P.M.

Figures 6, 7 and 8.—Automobiles entering and departing from the Loop or central business district observed by hours. June 27th, 1916.

Figure 9.—Analysis of Automobiles entering and departing from the Loop, showing percentages.

Figure 38.—Comparison of weekday traffic, Tuesday, June 27, 1916 and Sunday traffic July 16, 1916, observed by hours at Rush St.

Figure 39.—Michigan Av. & 12th St.

Figure 40.—Washington St.

Figure 41.—Jackson Blvd.

Figure 50.—Tabulation of all Automobiles entering and departing from the Loop showing percentage comparison and volume at each entrance.

Figure 51.—Automobiles entering and departing from the Loop giving percentage of those remaining by hours.

There were six traffic counts in all. The first count was during the period June 21, 22, 23, 24, 26 and 27, 1916. This count started at 7:00 A. M. and operated continuously without interruption until 7:00 P. M. All automobiles, except those used for commercial traffic, coming in to or going out of the central business district, at all points of ingress and egress, were counted, and a record by

license number and time of observation was kept of every car that came in and went out of this district for the period of six days. In addition, during this same period, the central business district was divided into blocks or groups of blocks, according to their locality. Observers were stationed so that at intervals of an hour all automobiles standing in these blocks were counted, the numbers of the automobiles noted, and other data recorded.

The purpose of this count was to ascertain the volume of traffic over all of the bridges and entrances into the central business district, its distribution over the central business district, and the daily fluctuation of traffic.

The average number of vehicles and automobiles counted each day during this count was 49,590, of which 15,634 passed the north side entrances, 13,615 passed the west side entrances, and 20,341 passed the south side entrances. Concurrently, there were counted during the five days vehicles standing in the various blocks of the central business district, and there was a record of over 800,000 observations.

SECOND TRAFFIC COUNT

June 29, 30, 31, 1916.
8:30 A.M. to 11:30 P.M.

Figures 10 and 11.—Automobiles using Rush St. Bridge, observed by hours. June 29th and 30th, 1916.

Figure 42.—Comparison of weekday traffic Thursday, June 29th, 1916, and Sunday, July 16th, 1916, observed hourly at Rush St.

Figures 52 to 61 inclusive are: A comparison of Automobiles and passengers stopping at certain buildings, June 29th and 30th, 1916, showing number stopping and of those the number that used Rush St. Bridge.

The second count was during the period June 29, 30 and 31, 1916. This count was started at 8:00 o'clock in the morning, and was kept continuously without interruption until 11:30 P. M. In this count there was noted every automobile crossing Rush Street Bridge and the arrival and departure of automobiles from 105 of the principal buildings, hotels, theatres, restaurants and other active office buildings within the central business district. The number of the vehicle as indicated by a license number was recorded, together with the number of passengers and time of observation.

The purpose of this count was to show the relative use of Rush Street Bridge and its importance to the owners and tenants in the buildings in the central business district.

On June 30th there was recorded going north at Rush Street Bridge in the period of 15 hours 7,723 automobiles, or an average of 515 per hour. The maximum number observed was 959 between the hours of 5:00 and 6:00 P. M. Going south on the same day

there were 7,278 automobiles, or an average of 485 per hour, with a maximum of 680 between the hours of 4:00 and 5:00 P. M.

On June 29th there were 869 automobiles carrying 1,613 passengers, which stopped at the Congress Hotel. Of this number 196 automobiles crossed the Rush Street Bridge with a total number of passengers amounting to 351. In other words, 22 per cent. of the automobiles and 21 per cent. of the passengers which stopped at the Congress Hotel used Rush Street Bridge.

On June 29th there stopped at the Willoughby Building, located at 2-8 South Michigan Avenue, 61 automobiles carrying 83 passengers. Of this number 34 automobiles carrying 45 passengers used the Rush Street Bridge, which reduced to percentage is 55% automobiles and 54% passengers.

THIRD TRAFFIC COUNT

July 17, 18, 19, 1916.
8:00 A.M. to 5:30 P.M.

Figures 12, 13 and 14—Commercial traffic count at Randolph St. and Michigan Ave. observed by hours. July 17, 18, 19, 1916.

Figures 15, 16 and 17—at Lake St. and Michigan Av.

Figures 18, 19, and 20—at So. Water St. and Michigan Av.

Figures 21, 22 and 23—at River St. and Rush St. Bridge.

Figures 24 and 25—at Rush St. and No. Water St.

Figuers 26 and 27—at Rush St. and Austin Av.

Figures 28, 29 and 31—at Rush St. and Illinois St.

Figures 30, 32 and 33—at Grand Av. and Rush St.

Figures 43, 44 and 45—Actual interruptions to traffic crossing Rush St. at Grand Av., Illinois St. and Austin Av. observed hourly, July 17, 18 and 19, 1916.

Figures 46, 47 and 49—Crossing Michigan Av. at River St. and South Water St., etc.

Figure 48—Comparison of Automobiles of June 27, 1916, and Commercial vehicles of July 18, 1916, absderved hourly at Rush St. bridge.

The third count was distinctly a commercial count, and was during the period July 17, 18 and 19, 1916, and started at 8:00 A. M. and was continued until 5:30 P. M. This count was 2½ hours shorter than the previous counts, because all of the freight houses and business houses closed at 5:30 P. M., and because of the rule that no teams were allowed to enter the railroad terminus just east of Michigan Avenue after 5:00 P. M. There was, therefore, and this is indicated by the count, a grand rush to get into the terminus before 5:00 o'clock, and at 8:00 o'clock in the morning. It was also noted in this count that the commercial traffic fell off very materially between 12:00 and 1:00 because at this time the teamsters had their regular one hour for luncheon, whereas the ordinary traffic materially increased from 12:00 to 1:00, because at

that time most of the business men were either returning from luncheon or going to one of the hotels or clubs for luncheon. A study of this traffic count shows that there were from forty to fifty stops or interruptions in traffic every hour, and that on an average 25 percent of the time spent in going from Randolph Street to Chicago Avenue was spent standing in Michigan Avenue. This is due to traffic regulation. The traffic was tied up for two or three blocks whenever the cross traffic was given the right of way of one-half a minute. This means that traffic was at a total standstill, and that when movement was resumed all pedestrians crossing the street were greatly endangered. In this count all delivery wagons, trucks, coal wagons, all commercial vehicles, horse, as well as self-propelled, except ordinary automobiles, were counted. The traffic crossing Michigan Avenue at Randolph Street and all other intersecting streets, as well as Rush Street, was counted.

The purpose of this count was to ascertain the amount of the east and west traffic in the cross streets and north and south business traffic on Rush Street Bridge and Michigan Avenue and its relation to the automobile traffic going north and south in Michigan Avenue.

The figures of the count show that the solution of the traffic problem necessitates the separation of the automobile and commercial traffic by placing each on its own plane.

Record was made of 28,274 east and west bound vehicles interrupting the north and south bound traffic. On July 19, 1,200 commercial vehicles crossed Michigan Avenue and South Water Street going west, interrupting the progress of 540 north bound automobiles and 261 south bound automobiles during a period of 9½ hours.

On the same day there was interrupted by the north and south automobile traffic 2,079 east and west bound commercial vehicles, averaging over 57 interruptions per hour, with a maximum of 67 interruptions between 1:00 P. M. and 2:00 P. M., in which hour 206 east and west bound commercial vehicles were delayed.

It is interesting to note that Monday and Saturday are low commercial traffic days, and that the commercial traffic is greatest from 3:00 to 5:00 in the afternoon. This is because of the custom of waiting for the last mail delivery for getting shipments to the freight houses before 5:00 P.M. This count shows 1,500 commercial vehicles mixing with 13,000 automobiles. The maximum interruptions recorded were at Austin Avenue and Rush Street, where there were 62 in one hour.

Figure 62, which is referred to at this point, is interesting in that it shows diagramatically increase and decrease of licensed vehicles in the City of Chicago. There is shown graphically on this digaram the number of horse drawn vehicles as well as self-propelled vehicles, from 1908 to 1916 inclusively. It will be seen from this chart that the number of horse drawn vehicles is on the decline, and that the use of the auto truck has been greatly increased.

FOURTH TRAFFIC COUNT

Sunday, July 16, 1916.
8:00 A.M. to 8:00 P.M.

Figure 34.—Automobiles crossing bridges observed hourly, July 16, 1916, at Rush St.

Figure 35.—At Washington St.

Figure 36.—At Jackson Blvd.

Figure 37.—At Michigan Av. & 12th St.

Figure 38.—Comparison of weekday traffic Tuesday, June 27, 1916, and Sunday traffic, July 16, 1916, observed by hours at Rush St.

Figure 39.—Michigan Av. & 12th St.

Figure 40.—Washington St.

Figure 41—Jackson Blvd.

Figure 42.—Comparison of weekday traffic Thursday, June 29, 1916, and Sunday, July 16, 1916, observed hourly at Rush St.

Figure 48.—Comparison of Automoblies of June 27, 1916 and Commercial vehicles of July 18, 1916, observed hourly at Rush St. Bridge.

The fourth count was a 12 hour count from 8:00 A.M. to 8:00 P. M. on Sunday, July 16th, 1916. In this count all automobile traffic not commercial passing the Rush Street Bridge and all entrances into the central business district, were counted. In fact, on this day the same methods were used in enumerating as to the automobile traffic in the central business district as were used on the first count. The purpose of the count was to compare the week day traffic with the Sunday traffic.

Record was made of 34,400 automobiles entering the central business district on Sunday as compared with 49,590 on week days. On July 16th there were 7,477 automobiles going north during the twelve-hour period at the intersection of 12th Street and Michigan Avenue. The maximum was between 7:00 P.M. and 8:00 P.M., when there were 1,108 counted. In addition there were 6,575 automobiles going south with a maximum of 906 between 7:00 and 8:00 P.M. Compare the above with the amount of traffic which crossed Rush Street Bridge, which is at the other end of Michigan Avenue, where 6,950 automobiles went north with a maximum of 800 between 4:00 and 5:00 P.M., and 5,835 automobiles going south with a maximum of 840 between 7:00 and 8:00 P.M.

One of the conclusions to be drawn from these traffic counts is that the automobile has become a means of transportation used by thousands of persons who can afford a rapid and exclusive service. The traffic counts taken show conclusively that 85 per cent. of the daily use of the automobiles using Rush Street Bridge and Michigan Avenue, as well as all other entrances into the central business district, is for business purposes.

FIFTH TRAFFIC COUNT

ILLINOIS CENTRAL COUNT

February 20-21, 1917.

7:00 A.M. to 6:00 P.M.

Figure 63.—Map showing location of places of observation for Illinois Central Count. 24 in all.

Figures 64 to 106, inclusive.—Tabulation of the traffic count at various stations shown on Figure 63 for Feb. 20 and 21, 1917, and hourly count from 7:00 A.M. to 6:00 P.M.

Figures 107, 108, 109 and 110.—Show graphically the flow of traffic for February 20 and 21, 1917.

Later it was decided to make traffic count five, which is known as the Illinois Central count. This traffic count started at 7:00 A.M. and continued without interruption to 6 P.M. for the period February 20 and 21, 1917. All traffic crossing Michigan Avenue from and to the Illinois Central and Michigan Central Railroad Freight Terminals was recorded. There were twenty-four points of observation located on figure 63. It is interesting to note at this point that there is a district east of Michigan Avenue, little known even to people living in Chicago, and practically little is known by most persons regarding the amount of business and traffic in this territory. There is a tract of land north of Randolph Street south of the Chicago River, east of Michigan Avenue, and bounded on the east by Lake Michigan, 74 acres in extent. In this district is the terminus of the Illinois Central Railway system, and the freight houses of the Illinois Central Railroad and the Michigan Central Railroad. Sixty-four acres of this territory is used as the Illinois Central terminal and ten acres as the Michigan Central Terminal. Thirty percent of all the business of the Illinois Central Railroad, a system of over 6000 miles of trackage, and amounting to approximately $2,000,000 per month, is done in the 64 acres above referred to. There are located large coal yards, the in and out freight houses of the Illinois Central Railroad, and several other large commercial houses. Coal and fruit are the largest commodities handled at this terminus. There is handled an average of 65 cars of fruit per day throughout the year, with a maximum of 100 cars during the busy season. There are 400 cars of in and out freight per day, a great proportion of which is conveyed by teams over the streets to various parts of the central business district. This enormous freight business brings about a great density of traffic on the streets leading to this freight terminus.

The purpose of this count was to show the effect and benefits of separating the commercial traffic and automobile traffic, as contemplated by the improvement of Michigan Avenue, upon the Illinois Central Freight Terminal.

It is interesting to note that at Station 23, located at the south end of the Illinois Central freight house, there arrived 65 loaded

vehicles and 212 empty vehicles, and there departed 253 loaded vehicles and 73 empty vehicles during the period of nine hours on February 21st. The loaded vehicles carried only package freight.

SIXTH TRAFFIC COUNT

Observed Hourly June 6-7, 1917.
7:00 A.M. to 6:00 P.M.

Figures 111, 112, 113 and 114, 115 and 116.—Tabulation and diagram of traffic count at South Water Street and Beaubien Court.

Figures 117 and 118, 119 and 120.—Lake St. and Beaubien Court.

Figures 121 and 122.—Randolph St. & Michigan Av.

Figures 123 and 124.—Shows graphically the flow of traffic on June 6 and 7, 1917, from 7:00 A.M. to 6:00 P.M.

Figures 125 and 126.—Graphical flow map of local traffic on Beaubien Court on June 6 and 7, 1917, from 7:00 A.M. to 6:00 P.M.

Figures 127 and 128.—Traffic interruptions at Michigan Av. and South Water St. observed hourly June 6 and 7, 1917 from 7:00 A.M. to 6:00 P.M.

Figures 129 and 130.—Graphical representation of Traffic interruption.

The sixth traffic count was made on June 6 and 7, 1917, between the hours of 7:00 A.M. and 6:00 P.M. There was a detailed count for two days of traffic on South Water Street and Beaubien Court, traffic at Lake Street crossing Beaubien Court, and traffic crossing Randolph Street and Michigan Avenue. The count was handled in the same manner as above indicated, and in addition the counters noted interruptions of traffic crossing Michigan Avenue at Randolph Street, Lake Street, South Water Street and River Street.

The purpose of this count was to show the effect the proposed closing of Lake Street to commercial traffic upon Beaubien Court and upon the Illinois Central Freight Terminal.

It is interesting to note that at Lake Street and Michigan Avenue during the period of 11 hours count on June 7, 1917, there were 696 commercial vehicles going to the Illinois Central Freight Terminal. Of this number 377 were loaded vehicles. There were 526 vehicles going west with 392 loaded vehicles. Compare this with the commercial traffic which passed South Water Street and Michigan Avenue; 1688 vehicles went west, of which 1220 were loaded and 1415 vehicles went east, of which 627 were loaded. The comparison calls attention to the fact that there was very nearly three times as much traffic on South Water Street as there was on Lake Street. Investigation showed that there was a short steep grade just east of Michigan Avenue on Lake Street, and that many teamsters knowing of this condition avoided taking their teams over the same, which in part accounts for the large volume of traffic on South Water Street.

ORGANIZATION

The immediate proximity of the University of Chicago helped very materially in the work of counting the traffic for the reason that the committee was enabled to secure 250 juniors and seniors who were studying economical conditions at the University as traffic counters. These men were all of high grade and took hold and did conscientious work. These men were paid at the rate of $5.00 per day of 12 hours. It was necessary to carefully train these men and drill them with captains, and assign relief squads so that the work of the count could go on without interruption. Before the count was made the men were thoroughly instructed as to their duties, with the result that on the morning of the first day of the first count the work went along as was contemplated, without any hitches.

In order that the first four of traffic counts above noted could be handled as expeditiously as they were it was necessary to divide the work into four subdivisions, or groups. One of the committee had charge of all the traffic entering the central business district from the north entrances. Another member of the Committee had charge of all traffic entering the central business district, from the west entrances. Another member of the Committee had charge of all traffic entering the central business district from the south entrances, and the remaining member of the Committee had charge of the traffic count by blocks within the central business district, at 261 stations. The men having been instructed as to the kind and location of their work, recorded the count in field note-books, a sample page of which is shown on Figure 3. In the first traffic count at 12th Street and Michigan Avenue, there were stationed sixteen traffic counters. With the consent of the South Park Commissioners an automobile was placed in Michigan Avenue, facing south, against the north bound traffic, and another automobile was placed facing north against the south bound traffic. These machines were placed in the center of each of the roadways, and the result was that all automobiles passing at this point had to go to one side or the other of the stationary automobiles. In each of these cars there were four counters. One man called the number of the car as it passed, the second man recorded it, the third man called the time and the fourth man acted as relief. This necessitated a slowing down of all of the traffic at this intersection which was handled in co-operation with the South Park police. An idea of this volume is shown by the record of 1350 cars in one direction in one hour. At Rush Street Bridge eight men were stationed, at Washington Street Bridge six men, at Jackson Blvd. Bridge, eight men. At the other places there were stationed two men, and frequently four men, where each man took traffic in one direction only, so as to avoid confusion. The observer noted the number of the car which passed, calling to the recorder the State license number, and if a foreign car, by calling the name of the State license tag. In addition, the observer at five

Specimen Sheet from Field Record Book
used in
MICHIGAN AV TRAFFIC COUNT
made by
BOARD OF LOCAL IMPROVEMENTS
CITY OF CHICAGO
1916 - 1917

	HOUR	HOUR	HOUR
	5-10 P. M.	5-12 P. M.	5-13 P. M.
1	17736	72049	8751
2	71341	64487	30586
3	42875	34447	153298
4	48108	Michigan	5872
5	21232	1543	81248
6	9569	19982	46905
7	15996	153659	33380
8	7215	56363	56417
9	13292	New Jersey	616
10	29154	68814	6283
11	67173	25292	85482
12	53550	4738	188509
13	Indiana	2682	94319
14	39508	129808	26189
15	11686	4946	178569
16	26696	75264	Wisconsin
17	34548	78317	30781
18	27762	51247	187606
19	171566	15365	81348
20	529	22541	20614

STATE OF ILLINOIS }
COUNTY OF COOK } SS

E. E. Mahannah, being first duly sworn on oath says that he resides at 1405 E 57th St., Chicago, Illinois, and that on the 26th day of June, 1916, between the hours of 5.10 Pm and 5.18 PM he counted all the automobile / commercial vehicles passing north / south / east / west at the intersection of Rush Street and Bridge Street, and that he also noted the license numbers attached to said vehicles and that the said count of vehicles and the said license numbers of the said vehicles were set down by him as above and are true and correct, and that said vehicles were all the vehicles of that character passing in that direction.

(Signed) E. E. Mahannah

SUBSCRIBED AND SWORN to before me this 27 day of June, A.D., 1916.

Notary Public

Figure 3

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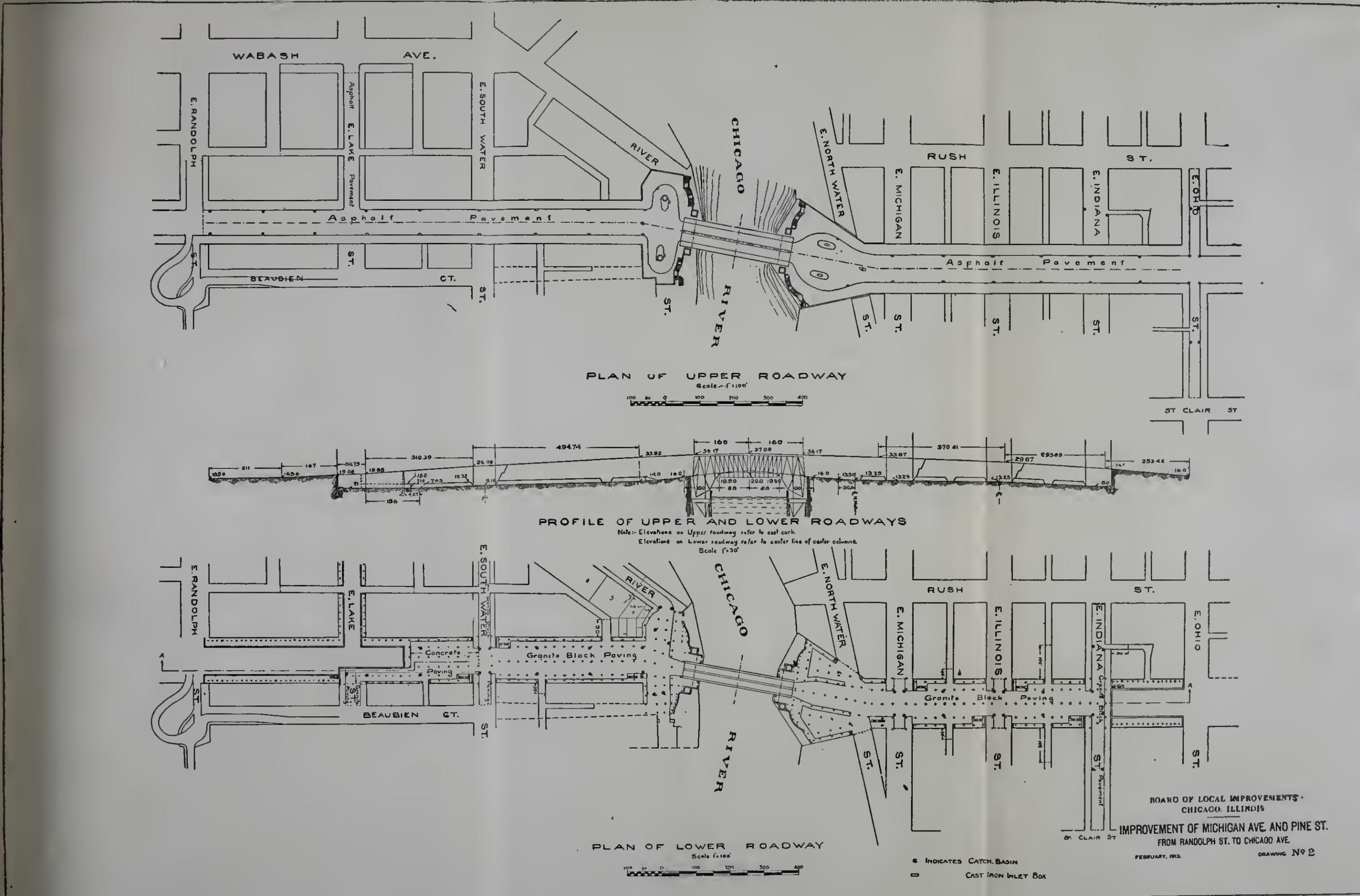

PLAN OF UPPER ROADWAY
PROFILE OF UPPER AND LOWER ROADWAYS
PLAN OF LOWER ROADWAY
BOARD OF LOCAL IMPROVEMENTS
CHICAGO, ILLINOIS
IMPROVEMENT OF MICHIGAN AVE. AND PINE ST.
FROM RANDOLPH ST. TO CHICAGO AVE.
FEBRUARY, 1913.
DRAWING No 2
Indicates Catch Basin
Cast Iron Inlet Box

Figure 2

minute intervals, depending entirely on the volume of traffic, would call the time so that between the time calls there would be a series of numbers showing the numbers of automobiles passing in the interval. Concurrently, all machines standing within the central business district were counted. Each block in the central business district was given a number, and the counter made a trip over each block every hour. These counters recorded time intervals, and the automobiles within the block during that interval by license numbers.

Upon the completion of the day's work each counter and observer reported to the office, and there made an affidavit before

Specimen of Ledger Card
Used in Office for Tabulating
MICHIGAN AV. TRAFFIC COUNT
BOARD OF LOCAL IMPROVEMENTS
CITY OF CHICAGO
1916 - 1917

Automobile No 116579 Owner W. O. Wheelock - M.D.

Residence Address 3148 Ainslie St. Business Address 220 S State St.

Date	Time	Place
Jun. 21, 16	10:00-11:00 A.M.	RUSH ST. BRIDGE GOING SOUTH
do.	10:00-11:00 A.M.	MICHIGAN AV. AND 12th ST. GOING SOUTH
do.	1:00- 2:00 P.M.	MICHIGAN AV. AND 12th ST. GOING NORTH
do.	1:39- 1:43 P.M.	Standing on Quincy St. Bet. Dearborn & State Sts
do.	2:30- 2:33 P.M.	Standing on Quincy St. Bet. Dearborn & State Sts
do.	3:32- 3:35 P.M.	Standing on Quincy St. Bet. Dearborn & State Sts
do.	4:32- 4:35 P.M.	Standing on Quincy St. Bet. Dearborn & State Sts
do.	5:22- 5:27 P.M.	JACKSON BLVD. BRIDGE GOING WEST
do.	5:40- 5:42 P.M.	JACKSON ST. BRIDGE GOING EAST
do.	6:00- 6:03 P.M.	Standing on Quincy St. Bet. Dearborn & State Sts
do.	6:00- 7:00 P.M.	RUSH ST. BRIDGE GOING NORTH
Jun. 22, 16	1:00- 2:00 P.M.	RUSH ST. BRIDGE GOING SOUTH
do.	2:00- 2:06 P.M.	Standing on Quincy St. Bet. State & Dearborn Sts
do.	3:00- 3:03 P.M.	Standing on Quincy St. Bet. State & Dearborn Sts
do.	4:00- 4:04 P.M.	Standing on Quincy St. Bet. State & Dearborn Sts
do.	4:30- 4:43 P.M.	JACKSON ST. BRIDGE GOING WEST

Fig. 4

a Notary as to the correctness of his work. These books were then turned over to the clerical staff under Wm. P. J. Halley, an expert accountant, and formerly Secretary of the Committee on Uniform Freight Classification. Under him there were some 62 men. Each traffic book when turned over by the observer, having been duly acknowledged, was dated on the front and rear covers, and properly identified by stating the contents, location and name of the observer, and recorder, and the hours of observation. The next step was the recording of this information on ledger cards 5 x 8 inches in size, as shown on Figure 4. A ledger card was made out for each and every automobile having an Illinois license number, and from the field note-books there was recorded the number and the point of observation, the direction of travel, or if the machine were stand-

ing, its position and the hour. The name of the owner of the automobile and his address were secured from the list of automobile licenses issued by the Secretary of State of the State of Illinois, which volume is issued monthly. On the cards themselves the location of the machine, when standing, was recorded in black ink, and its location, when moving, was recorded in red ink. On the fac-simile of the card here shown, in order to obviate the color scheme, the capitalized items show machines in motion, and the other items, machines standing.

The magnitude of this undertaking can be readily imagined from the statement that there were 851 field books compiled, and tabulated on these ledger cards. The cards give a very complete history chronologically of the automobiles which entered the central business district, and their movements within the district. From the ledger cards some of the tabulations and diagrams herewith shown were compiled.

The following statistics regarding the magnitude of the first count may be of interest. There were 43,761 different Illinois automobiles counted during the period of the first count. The movements of the 43,761 automobiles was recorded on 74,400 ledger cards, which contained 436,050 items, of which 299,610 are incoming and outgoing movements and 136,440 are records of machines found standing within the central business district.

A study of the ledger card, showing the date, time and place of observation, or its movement, readily classified the car as one used for business or pleasure. The study further proved that the automobile is not solely a pleasure vehicle but that on the contrary it is distinctly a business vehicle. The following table shows an analysis of the gross figures for the first count, June 21, 22, 23, 24, 25, 27, 1916, from 7:00 A.M. to 7:00 P.M. of vehicles in and out of the central business district.

Vehicle	No. of cars	%	Movements	%
Business	29674	67.80	252258	84.19
Pleasure	14089	32.20	47352	15.81
Totals	43763	100.	299610	100.

Of the 43761 cars the 19713 or 45% went over the Rush Street Bridge.

	No. of cars	%	Movements	%
Business	13367	67.30	70760	86.87
Pleasure	6346	32.70	10689	13.13
Totals	19713	100.	81449	100.

From the field record and ledger cards, tabulations and diagrams, figures 6 to 130 inclusive, were compiled. On the drawings there is shown diagramatically the volume of traffic crossing Michigan Avenue and Rush Street at all of the intersecting streets between Randolph Street and Grand Avenue. All lines are drawn to

the same scale throughout, graphically indicating the relative volumes of traffic at the various intersections. The arrows on the diagrams show the direction of travel and the figures indicate the actual number of vehicles counted.

TRAFFIC COUNT BY WEST CHICAGO PARK COMMISSIONERS

The traffic counts made by the West Chicago Park Commissioners, which are shown in Figures 131 to 134, inclusive, are given here so that a comparison can be made of the volume of purely pleasure traffic on Jackson Boulevard and Washington Boulevard, at points a mile or more distant from State Street, with the traffic as indicated in the first traffic count. The Park Commissioners' traffic count is interesting in that on Figure 131 there is a comparison of traffic taken at the same point. The second count was taken four years after the first, and shows a decided diminution in the use of horse-drawn pleasure vehicles on the boulevards.

THE PAVEMENTS AFFECTED BY THE TRAFFIC

Coupled with the subject of traffic is the pavement upon which the traffic moves. Michigan Avenue, from 12th Street to 11th Street, is an asphaltic concrete pavement, with an 85-foot roadway. The wearing surface is 2 inches in thickness, laid on a foundation of 6 inches of Portland cement concrete. From 11th Street to Jackson Boulevard, the roadway is 75 feet in width, with the same character of pavement above noted. The pavement from 12th Street to Jackson Boulevard was laid in 1909, and has a total yardage of 35,402 square yards at a contract cost of $66,457.53, which price included a guaranty for a period of 5 years. The maintenance cost for this stretch of pavement during the year 1917 was $415.00.

That part of Michigan Avenue, from Jackson Boulevard to Randolph Street, has a 75-foot roadway and was paved in 1911 with an asphaltic concrete wearing surface 2 inches in thickness on a macadam foundation 12 inches in thickness. The total yardage was 19,500 square yards, and the cost approximately $30,000.00. The maintenance for the year 1917 was $450.00.

Michigan Avenue, from Randolph Street to River Street, has a 38-foot roadway, and was originally a granite block pavement laid on a base of macadam and cinders in 1888. The large volume of traffic, as indicated in this paper, brought a corresponding amount of complaint from the automobile owners on account of the roughness of the surface of the old granite block pavement. Pending the widening of Michigan Avenue, it was decided, as an experiment, to surface the granite block with asphalt. This was accomplished by thoroughly cleaning the old blocks and raking the dirt out of the joints with raking irons. The surface of the granite block was painted with asphaltic cement and on top of this surface there was a thoroughly rolled and bonded sheet asphalt pavement with a minimum thickness of 2 inches; at the joints this thickness

was considerably over 3 inches. Where the granite blocks were too high to make a proper and smooth pavement, the granite was relaid so that over the entire surface was laid the two inches of asphalt. A careful record has been kept of the maintenance on this stretch of experimental pavement. There was originally laid 5,985 square yards of asphalt at a cost of $5,412.30. This asphalt was laid in June, 1913, at a cost of 90.4 cents per square yard. The table below shows the amount of maintenance on this resurfaced granite block for each year, and it is interesting to note that at the end of 3½ years there was replaced 16.7% of the original surface at a cost of 20.7% of the original cost. The figures here given do not include any cost for overhead, which amounts in this case to approximately 20%.

Michigan Avenue, from Randolph to River Street. Resurfaced June 3 to 7, 1913. 5,985 sq. yds. Cost—$5,412.30, or $.904 per sq. yd.

Year	Yardage of Repairs	Percentage of Whole	Cost of Repairs	Percentage of Original Cost	Cost per Yard
1913	16	.27	$ 45.62	.84	$2.89
1914	178	2.97	192.02	3.55	1.08
1915	302	5.04	314.48	5.81	1.04
1916	503	8.42	565.70	10.45	1.12
Totals for 3 yr. 7 mo.	999	16.70	1117.82	20.70	1.12

Randolph Street east of Michigan Avenue was paved with granite block in 1887, and west of Michigan Avenue with creosoted wood block in 1910.

Lake Street, to the east and to the west, has a granite block pavement, laid in 1887.

South Water Street, to the east and to the west, has a granite block pavement, laid in 1883.

At River Street and approach to the Rush Street Bridge there is a granite block pavement, laid in 1896.

Rush Street Bridge has an oak block pavement laid upon creosoted plank, laid in March, 1917. There are two roadways on this bridge, and the width of each roadway is 17½ feet.

Rush Street, from the River to Austin Avenue, has a granite block pavement, laid in 1910. From Austin Avenue to Ohio Street, there is a granite block pavement, laid in 1896.

Austin Avenue, has a granite block pavement 46 feet in width, laid in 1902.

Illinois Street has a granite block pavement 46 feet in width, laid in 1901.

Grand Avenue has a granite block pavement, with a street car track, laid in 1903.

Ohio Street has an asphalt pavement, laid in 1902.

DISCUSSION

The Chairman, Mr. H. E. Hudson, M. W. S. E.: The degree of completion that obtains in the various cities throughout the country would be very interesting data if it could be put in the form of a chart to show the progress in the physical completion of the plan. The position of Chicago with relation to other cities who are operating under such a comprehension, well co-ordinated city plan would be interesting as compared to other cities. But Chicago is making progress. It is accomplishing its Greater Chicago Plan and without going into the details of the various steps that have been accomplished, we have listened tonight to one phase of the Michigan Avenue Improvement, which is a portion of the Greater Chicago Plan. The originators of these city plans are not always engineers, nor are they engineers in the majority of cases, but it is interesting to note that the attention of the engineer is being drawn closer and closer to City Plans and when it comes to the actual completion of the City Plan the engineer certainly comes into his own. He is called in to work out the intricate and complicated details. The design of the Michigan Avenue Improvement was made in the office of the Board of Local Improvements. Mr. Lenth has given us an analysis of the traffic surveys which were made in connection with the Michigan Avenue Improvement, to determine the relation which the improvement would have to the down-town traffic. Some of the conclusions which are reached in such analysis are very startling. It is hard to grasp the whole thing in one hearing of such a paper, but the work which has been done is one that is remarkable in itself, and will surely be of great interest to all of the engineering world. Proably no more intricate or complicated survey has been made than the one made for this purpose.

I am quite sure that we have all been entertained and enlightened by the discussion of such a traffic study. I am also quite sure that until I saw it I didn't realize the full extent of the Michigan Avenue Traffic Survey, even though I was located in the same office from which the improvement is being handled. It is especially interesting to engineers to see the German espionage which was practiced in the observing of the automobile numbers and the time of the observation throughout the Loop so that each car was traced from one place to another and its movements detected and its character analyzed, so we could tell whether it was being used for pleasure or business, and it is astonishing to me to find that 85 per cent. of the automobile traffic is used for business purposes. I didn't have any idea that the percentage was as high as that.

In the studies in connection with Park Commissioners I am wondering if such an analysis wouldn't apply to a large extent to the traffic which they count on the boulevards, and if this analysis wouldn't show that the automobile is really being used for business purposes, and is really a business vehicle.

Mr. Stevenson: I would like to ask about two questions. In the first place, in counting the movement of the vehicles, since

those cards show the number of passengers carried, and the number arriving at and leaving those buildings, how was that counted? Was there a man at each of those buildings?

Mr. Lenth: Men stationed at the Rush Street Bridge, one of which counted the number of passengers in each automobile as it passed the bridge and another who recorded the count together with the number of the automobile and the time. At 105 of the principal office buildings similar details were stationed, and it was from this count that the table was prepared. This count must not be confused with the information which was tabulated on the 5 by 8-inch cards. In fact, the latter was a distinctly different count from the former. In the latter case no count was made of the number of passengers in the vehicles and the patrol observer made record of the time at which he was in the block and made a record of the automobile numbers he found therein.

Mr. Ray Seely, M. W. S. E.: Is there any way of showing what area of the street was covered by the traffic? In other words, to make a comparison of a certain number of vehicles passing over a twenty foot stretch, with the number passing over a narrower stretch in a given time, and as to what the maintenance would be on the two.

Mr. Lenth: The maintenance cost on a seventy-five foot roadway is approximately one-half of that, in a three and one-half year period, on a thirty-eight foot roadway, so that we would infer that pretty much of that pavement is being used. If you have ever ridden up and down some of these streets during the peak periods you will realize that. That condition is true both North and South of Randolph Street.

Mr. T. L. D. Hadwen, M. W. S. E.: With reference to the maintenance of the asphalt pavement was any record kept as to whether the movement of the granite block had anything to do with it? I understood they were going to see what results could be obtained from turning over the granite blocks and resurfacing over the top.

Mr. Lenth: The granite blocks were the foundation for the sheet asphalt in Michigan Avenue and the granite block was originally laid on a foundation of macadam and cinders, which was slightly unstable. The original surface of Michigan Avenue was about 5 feet above datum, or the average level of Lake Michigan, and from time to time it was filled so that the present surface is about 14 feet above datum. In other words, the depth of filling was 9 feet, and was fairly well settled before the asphalt pavement was placed upon the old granite block pavement. The principal trouble north of Randolph Street was not from the unstable foundation of the pavement but rather from openings made in the asphalt and granite block pavement.

Mr. O. F. Dalstrom, M. W. S. E.: What length of time is contemplated for the carrying out of the improvements you have outlined here?

Mr. Lenth: If we were working under normal conditions this improvement could be completed in about two years, but under

the existing conditions I would scarcely want to venture a guess as to the length of time it will take. I don't even know whether we could get the steel to start on the bridge itself. It is contemplated to get the foundations and the caissons in for the bridge itself as soon as possible, and to begin removing the buildings North of Randolph Street. But there has been no work done as yet.

Mr. W. W. De Berard, M. W. S. E.: Was there a ball game on June 26th if it had any effect between three and five going South?

Mr. Lenth: I hadn't thought of a ball game, but there may be something in that. I hadn't gone far enough along to ascertain the real reason, because that fluctuation is practically the same for the five successive days.

Mr. A. J. Schafmayer, ASSOC. W. S. E.: What effect did this evidence have in determining the benefits of the improvements? Did it fulfill the claims of the City and was it worth the money it cost on that basis, not merely from a scientific basis alone, but from a practical standpoint? The original purpose was to show the benefits to the different parts of the property assessed, and was it satisfactory in that regard?

Mr. Lenth: Judge Pond who is trying that case, thought very highly of that information, but to what extent that entered into his judgment I am unable to say. The final decision has not been entered as yet, and I haven't talked to Judge Pond as to that particular phase of the subject. In fact, I thought it best not to talk to him about it, although he is intensely interested in this traffic count. But I have no hesitancy in saying it was worth every cent we paid for it, and it was with that point of view in mind that I hated to see all that good information go to waste, and thought it sufficiently valuable to transcribe it and present it to this society.

Mr. Stevenson: Were these figures, traffic counts, etc., used in any way in determining the assessment of the various properties and the area benefitted by the improvement?

Mr. Lenth: No, they were not. The improvement is to be paid for by special assessment and a bond issue. The assessment is spread upon the property benefitted, and the bond issue of about three million dollars is the tax on the general public.

Mr. Stevenson: Do you consider in the assessment only the frontage on the street, or the area benefitted?

Mr. Lenth: Assessment for the improvement of Michigan Avenue is spread over the district bounded on the north by North Avenue and east of Clark Street as far south as Chicago Avenue, and east of Wells Street as far south as the Chicago River, the entire loop district east of the Chicago River as far south as Taylor Street, and the property east of State Street as far south as 31st Street, with the exception of a triangle contiguous to the Lake, between 22nd Street and 31st Street. There was, however, a very considerable assessment placed on the property immediately abutting the line of the improvement. The amount of benefit and the district to be assessed were determined by commissioners who were appointed by the County Court.

Mr. Stevenson: The reason I asked that question is that there has been considerable discussion lately, that instead of assessing the frontage, it should be divided up into zones and assessed according to its zone of influence.

Mr. Lenth: As a matter of fact, according to the Illinois Law you can assess a property the amount it is benefitted,—no more and no less. That is, of course, distinctly apart from this paper, and I have refrained from talking about the assessment feature, because only a few of us are intimately interested in a part of that paper.

Mr. Schafmayer: Wouldn't a study of this evidence tend to show to a great extent the limits of the zone benefitted?

Mr. Lenth: If carried far enough it would help very materially.

Mr. Schafmayer: By studying the ownership of the various machines, it should show it very plainly. For instance, you had an illustration tonight showing a piece of property up on Ainslie Avenue benefitted by this improvement.

The Chairman: I think one of the engineering details which would have been interesting would have been a comparison of vehicle weights in the commercial end of it, to show the amount of traffic that went here or there.

Mr. Lenth: The opposing interests, the objectors to this improvement made no traffic counts themselves, except the usual count which is made that four hundred or five hundred vehicles went over a bridge in a day, and when they began to show what they had, as compared with the complete analysis that we made, they actually did not present their traffic count, because it could have been shot to pieces very readily. It wasn't taken with sufficient detail for this purpose.

Member: What was the effect of this improvement on the traffic to and from the Illinois Central District, as to advantages. That is, was it advantageous to them or disadvantageous?

Mr. Lenth: As to the effect of the widening and double-decking of Michigan Avenue upon the traffic to and from the Illinois Central district, the very fact that the ordinary automobile pleasure traffic is separated from the commercial traffic by double-decking the thoroughfare is of great importance to the Illinois Central Terminal. In the trial of the case that feature was brought out very strongly by the Illinois Central Railroad and the City of Chicago. The traffic counts herein given played a very important part in its determination.

Mr. Stevenson: Was any record kept of what amount of freight hauled had its general destination within the Central Business District and what went beyond the Central Business District?

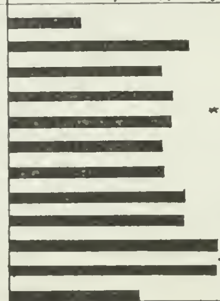
Mr. Lenth: No, the volume of traffic, as indicated by this count was so large that you couldn't go into very much further detail without increasing the cost immensely. There would be too much to go into to determine that.

Automobiles Entering & Departing from the Loop
VIA NORTH SIDE BRIDGES Observed by hours °June 27 1916

TIME	RUSH ST North	RUSH ST South	STATE ST. North	STATE ST. South	DEARBORN North	DEARBORN South	CLARK ST North	CLARK ST South	WELLS North	WELLS South	Total North & South
7 to 8	120	360	11	2	x 10	14	11	15	19	18	580
8 - 9	232	860	9	15	x 35	60	29	40	110	x 80	1450
9 - 10	300	560	15	115	x 30	16	30	55	36	81	1238
10 - 11	420	620	19	13	x 30	50	25	35	48	58	1318
11 - 12	460	523	21	19	x 40	53	46	42	44	64	1312
12 - 1	647	249	14	9	x 45	47	26	35	95	x 75	1242
1 - 2	468	440	29	16	36	40	55	x 50	60	60	1254
2 - 3	508	808	18	16	39	48	54	35	59	30	1413
3 - 4	630	500	41	9	29	48	40	26	59	22	1404
4 - 5	*700	598	74	16	47	56	46	36	60	60	1693
5 - 6	667	500	80	22	92	56	120	24	69	46	1676
6 - 7	517	254	35	7	51	36	53	24	51	26	1054
12 hrs	5669	6070	366	259	484	524	535	417	710	600	15,634

Time — Volume of Traffic by hours

x Estimates.
° Tuesday



1A

*Actual count from 4[25] to 4[55] was 232 to make Table complete from 4 to 5 700 was estimated for the hour. On all other x estimates there was no complete data.
Total amounts estimated - 843
Leaves as actually counted 14,791
■ = 100

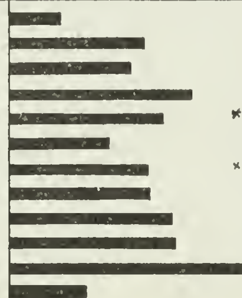
Figure 6

Automobiles Entering & Departing from the Loop.
via WEST SIDE BRIDGES observed by hours June 27° 1916.

TIME	RANDOLPH East	RANDOLPH West	WASHING'N East	WASHING'N West	MADISON East	MADISON West	ADAMS E'st	ADAMS W'st	JACKSON East	JACKSON West	V'BUR' E.	V'BUR' W	HAR'SN E	HAR'SN W	POLK E	POLK W	TOTAL E & W
7 to 8	5	7	120	60	40	20	15	20	20	100	x 1	x 1	2	2	2	4	419
8 - 9	6	18	280	120	20	20	25	40	360	200	2	2	4	3	1	4	1105
9 - 10	11	23	280	160	30	20	20	40	140	250	0	2	8	7	2	0	993
10 - 11	11	28	440	200	35	40	35	40	340	*300	2	6	4	6	1	0	1488
11 - 12	19	23	280	159	40	60	25	20	340	x 300	2	1	2	4	5	3	1283
12 - 1	10	12	200	140	14	47	23	35	120	180	4	5	3	5	4	1	803
1 - 2	11	27	240	180	30	40	15	35	220	317	8	6	9	5	2	1	1146
2 - 3	17	33	270	210	30	40	25	25	180	300	2	6	4	7	2	2	1153
3 - 4	18	x 15	220	270	35	60	18	20	300	360	7	8	3	1	4	4	1343
4 - 5	13	27	220	260	45	40	32	20	320	360	4	6	6	3	3	2	1361
5 - 6	16	19	220	460	40	60	30	40	360	540	1	5	8	7	2	3	1811
6 - 7	4	x 5	123	173	41	32	28	38	103	153	3	4	1	1	1	2	630
12 hrs	141	237	2893	2392	400	479	289	373	2803	3360	36	52	54	51	29	26	13,615

TIME — Volume of Traffic by Hours

° Tuesday



1B

* On Jackson Blvd. the only record was 50 Autos from 10 to 10[04] am.
x 300 is estimated for 10 to 11 am. No record on hand for 11 to 12 am. No record for any other x on this page.
Total amounts estimated = 572
Leaves as actually counted 13043
■ = 100
x estimated.

Figure 7

Automobiles Entering & Departing from the Loop, via all SOUTH SIDE ENTRANCES Tuesday June 27th 1916

	MICHIGAN-12th		WABASH-12		STATE-11		Clark-Taylr		5th-Taylor		Ind^a 12th		Total
TIME	North	South	North	South	Nor.	Sou.	Nor.	Sou.	Nor.	Sou.	Nor.	Sou.	by hours
7 to 8	475	280	3	4	2	3	2	–	2	–	–	–	771
8-9	609	720	6	16	4	3	4	4	4	7	–	3	1380
9-10	1010	820	14	20	5	0	5	8	5	3	–	2	1892
10-11	938	780	23	25	3	7	9	11	9	13	–	1	1819
11-12	978	1021	16	24	7	5	8	10	6	2	–	4	2081
12-1	888	601	15	20	3	0	×10	13	2	1	–	–	1553
1-2	.888	748	24	35	10	6	11	14	4	4	–	2	1743
2-3	1062	560	20	19	7	9	4	13	3	2	–	1	1700
3-4	1048	882	16	23	9	6	7	11	6	2	–	3	2019
4-5	1142	1028	11	17	8	6	7	13	10	3	–	2	2247
5-6	1091	1105	22	20	6	2	11	17	2	6	–	5	2287
6-7	582	257	13	20	3	4	–	1	1	3	–	2	886
	10711	8799	183	243	67	51	78	115	54	46	–	25	20372

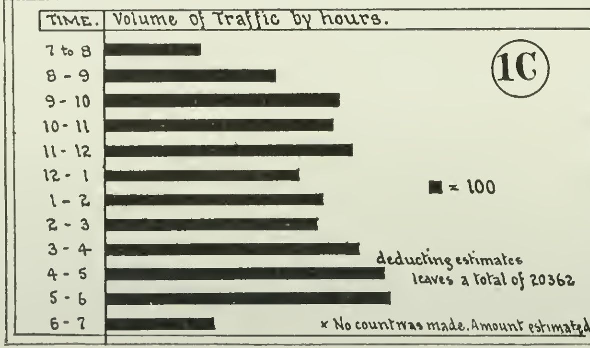


Figure 8

Automobiles Entering & Departing from the Loop from 7am to 7pm June 27th 1916 Tuesday

North Side.

	SOUTH	NORTH	Total	Per Cent	Traffic Volume at each bridge.
1 Rush St	6070	5669	11739	75%	
2 State "	259	366	625	4%	
3 Dearborn	524	484	1008	6½%	
4 Clark "	417	535	952	6%	
5 Wells "	600	710	1310	8½%	
	7870	7764	15634	100%	■ = 600 Autos

2A

West Side.

	EAST	WEST	Total	Per Cent	Traffic Volume at each bridge
1 Randolph St	141	237	378	2½%	
2 Washington	2893	2392	5285	39 %	
3 Madison "	400	479	879	6½%	
4 Adams "	289	373	662	5 %	
5 Jackson	2803	3360	6163	45 %	
6 Van Buren "	36	52	88	½%	
7 Harrison	54	51	105	1 %	
8 Polk-Taylor	29	26	55	½%	
	6645	6970	13615	100%	■ = 600

South Side.

	NORTH	SOUTH	Total	PER CENT	Traffic Volume at each entry
1 Mich. & 12th	10711	8799	19510	96%	
2 Wab. & 12th	183	243	426	2%	
3 State & 11th	67	51	118	½%	
4 Clark-Tayl'r	78	115	193	1%	
5 5th Av- "	54	46	100	½%	
6 Ind^a 12th	–	25	25		
	11993	9279	20372	100%	■ = 600

Figure 9

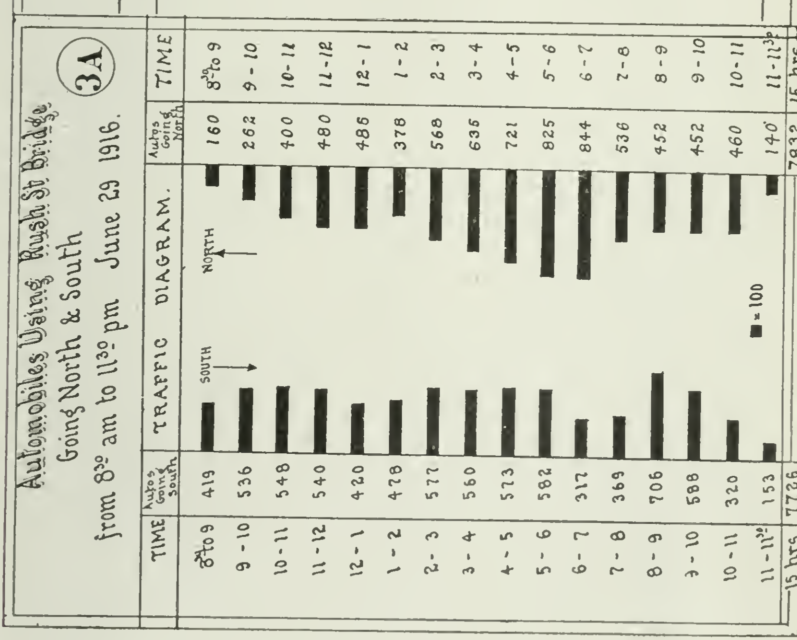


Figure 10

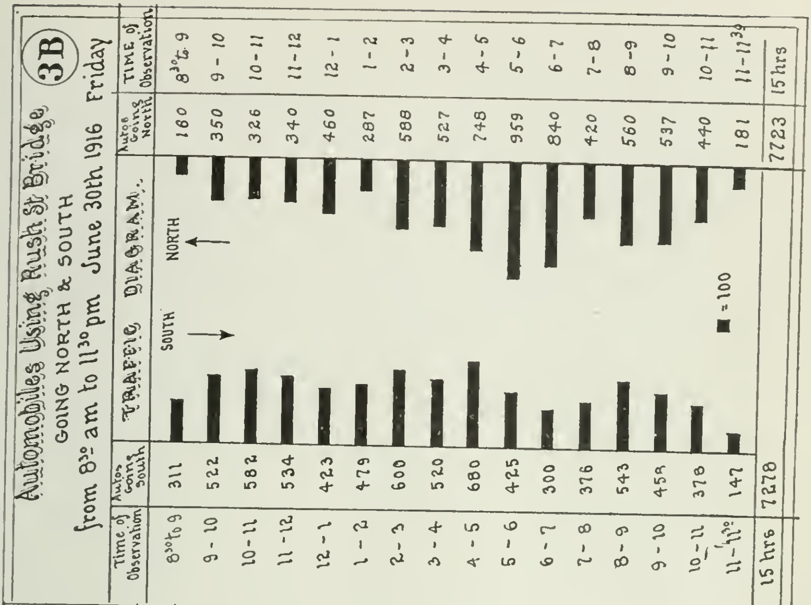


Figure 11

Commercial Traffic Count at Randolph & Mich Av from 8am to 5³⁰pm July 17th 1916. **4A**

Time	N.E. COR W.	N.E. COR N.	N.E. COR S.	S.W. COR E.	S.W. COR N.	S.W. COR S.	Total both Corners by hours.
8 to 9	26	–	2	45	33	2	109
9-10	48	9	7	62	42	-	176
10-11	57	3	5	53	52	-	173
11-12	59	-	6	43	37	-	146
12-1	24	3	5	23	20	-	75
1-2	29	3	4	35	30	-	101
2-3	48	4	6	66	37	3	165
3-4	74	-	7	52	43	-	179
4-5	64	2	7	55	26	-	155
5-5³⁰	25	2	1	11	1	-	39
9½ hrs	453	26	50	445	320	5	1318

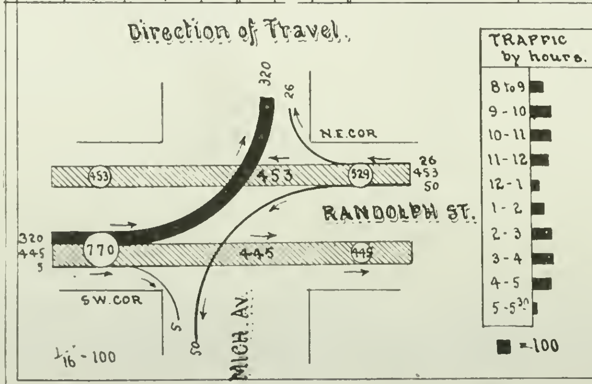


Figure 12

Commercial Traffic Count at Randolph & Mich Av. from 8am to 5³⁰pm July 18th 1916. **4B**

	N.E. COR. W.	N.E. COR. N.	N.E. COR. S.	S.W. COR E.	S.W. COR N.	S.W. COR S.	Total both Corners by hours.
8 to 9	37	3	1	51	49	–	141
9-10	56	6	2	64	35	1	164
10-11	67	7	10	52	49	–	185
11-12	65	3	9	47	35	–	159
12-1	24	3	9	20	21	–	77
1-2	46	4	6	39	34	1	130
2-3	83	5	10	59	26	1	184
3-4	55	3	7	66	25	2	158
4-5	64	5	8	55	29	1	182
5-5³⁰	25	–	–	17	8	–	50
	502	39	62	470	311	8	1390

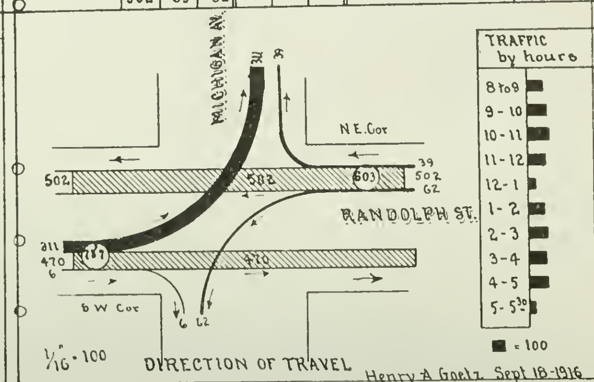


Figure 13

Commercial Traffic Count at Randolph & Mich Av. from 8am to 5^30 pm July 19th 1916.

4C

	N.E.COR			S.W.COR.			TOTAL
Time	W.	N.	S.	E.	N.	S.	by hours
8 to 9	56	2	2	45	47	1	153
9-10	60	3	—	48	31	—	142
10-11	59	2	10	64	56	—	191
11-12	56	6	3	36	43	1	145
12-1	21	3	8	19	9	1	61
1-2	55	4	11	46	29	—	145
2-3	58	7	4	73	38	3	183
3-4	62	3	3	63	30	3	164
4-5	50	6	4	67	14	1	142
5-5^30	16	2	—	9	3	—	30
9½ hrs	493	38	45	470	300	10	1356

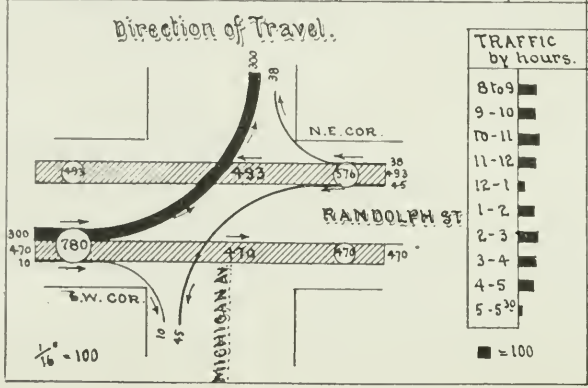


Figure 14

Commercial Traffic Count at Lake St & Michigan Av. from 8am to 5^30 pm July 17th 1916

5A

	S.W.COR.			N.E.COR			BOTH
TIME	E.	S.	N.	W.	N.	S	CORNERS
8 to 9	59	-	15	60	-	-	134
9 - 10	67	-	20	84	1	5	157
10 - 11	72	8	14	60	-	2	164
11 - 12	60	6	7	56	-	7	126
12 - 1	16	1	8	33	3	4	65
1 - 2	47	5	6	37	-	2	97
2 - 3	75	2	10	77	-	5	169
3 - 4	82	3	16	78	-	6	185
4 - 5	84	9	13	73	2	-	181
5 - 5^30	14	1	1	33	-	-	49
9½ hrs	566	33	110	571	6	31	1317

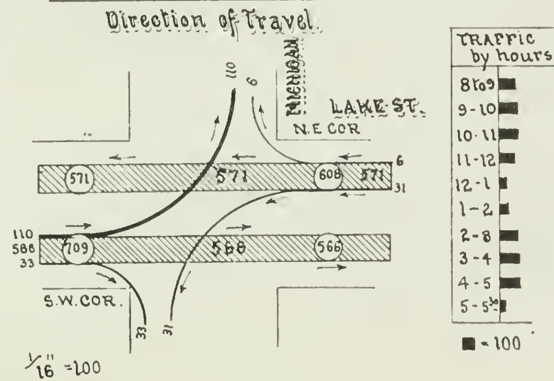


Figure 15

Commercial Traffic Count at Lake St & Michigan Av. from 8am to 5³⁰ pm July 18th 1916.

5B

TIME	S.W COR. E.	S.W COR. S.	S.W COR. N.	N.E. COR. W.	N.E. COR. N.	N.E. COR. S.	BOTH CORNERS
8 to 9	56	4	6	60	1	3	130
9 - 10	60	2	18	68	2	8	158
10 - 11	65	12	10	62	–	3	152
11 - 12	56	8	15	69	2	4	154
12 - 1	24	4	6	32	–	3	69
1 - 2	68	5	10	39	2	6	125
2 - 3	111	6	8	66	2	4	197
3 - 4	81	4	7	72	1	–	165
4 - 5	88	6	13	68	2	1	188
5 - 5³⁰	9	2	3	26	–	1	41
9½ hrs	613	53	96	552	12	33	1359

Direction of Travel.

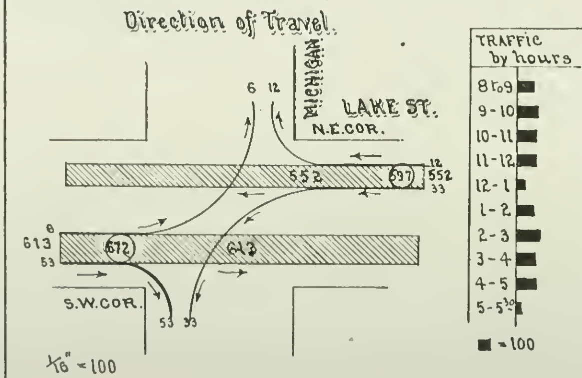


Figure 16

Commercial Traffic Count at Lake St & Michigan Av. from 8am to 5³⁰ pm July 19th 1916.

5C

TIME	S.W.COR. E.	S.W.COR. S.	S.W.COR. N.	N.E.COR. W.	N.E.COR. N.	N.E.COR. S.	BOTH CORNERS.
8 to 9	66	5	10	63	1	4	149
9 - 10	89	4	13	90	1	5	182
10 - 11	74	5	10	64	–	3	156
11 - 12	51	3	10	71	2	2	139
12 - 1	18	3	3	40	2	3	69
1 - 2	50	7	12	39	–	5	113
2 - 3	76	3	9	48	–	5	141
3 - 4	71	1	14	74	1	2	163
4 - 5	76	6	7	58	3	–	150
5 - 5³⁰	8	4	1	25	–	–	38
9½ hrs.	559	41	89	572	10	29	1300

Direction of Travel.

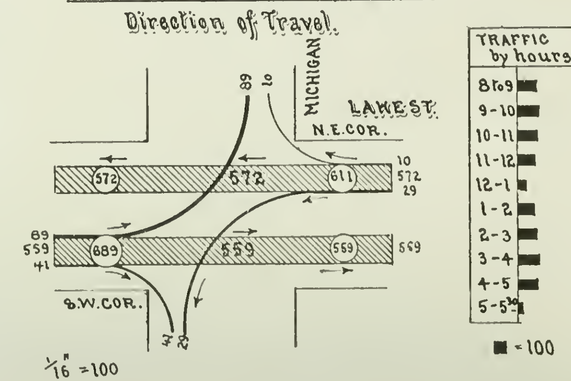


Figure 17

Commercial Traffic Count at So. Water & Mich. Av. from 8am to 5³⁰ Pm. July 17th 1916. (6A)

Time of observation	S.E. COR. N.	S.E. COR. E.	S.E. COR. W.	N.W. COR. S.	N.W. COR. E.	N.W. COR. W.	S.W. COR. E.	S.W. COR. N.	S.W. COR. S.	N.E. COR. W.	N.E. COR. N.	N.E. COR. S.	Total by hrs
8 to 9													
9³⁰-10	21	17	2	12	7	2	47	3	2	55	10	3	181
10-11	31	26	3	34	21	11	67	6	1	130	15	17	362
11-12	21	14	2	21	17	6	63	6	3	138	21	9	321
12-1	18	4	2	21	5	6	35	3	2	52	7	1	156
1-2	25	14	1	18	17	3	74	8	2	79	5	7	263
2-3	23	17	2	32	24	3	95	3	2	138	21	7	367
3-4	33	18	2	17	33	9	118	—	2	145	15	16	408
4-5	33	11	3	28	41	2	155	2	3	145	25	4	452
5-5³⁰	7	—	—	12	7	—	28	3	—	81	16	—	154
8 hrs	212	121	17	195	172	42	682	34	17	963	135	64	2654

Direction of Travel.

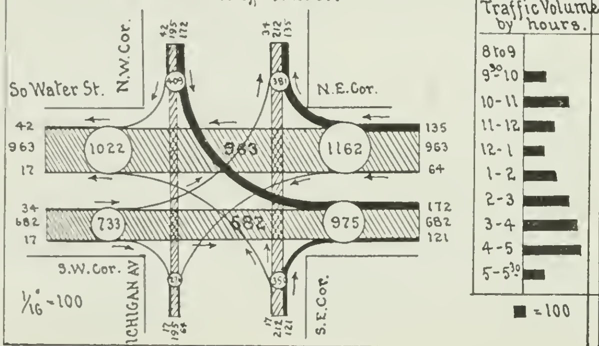


Figure 18

Commercial Traffic Count at So. Water & Mich. Av. from 8am to 5³⁰ Pm. July 18th 1916. (6B)

Time of Observation	S.E. Cor. N	S.E. Cor. E	S.E. Cor. W	N.W. Cor. S	N.W. Cor. E	N.W. Cor. W	S.W. Cor. E	S.W. Cor. N	S.W. Cor. S	N.E. Cor. W	N.E. Cor. N	N.E. Cor. S	All Corners Total by hrs
8 to 9	23	16	2	25	28	5	94	3	3	101	23	7	330
9-10	40	17	1	19	12	8	91	5	4	130	17	8	350
10-11	43	14	2	31	27	8	86	3	0	122	17	15	368
11-12	33	11	4	37	19	8	62	5	4	120	23	13	329
12-1	15	5	0	17	7	4	27	1	10	53	7	5	151
1-2	26	17	1	22	24	5	82	1	0	93	9	12	292
2-3	32	12	4	46	26	14	113	5	2	116	15	2	387
3-4	13	18	4	27	24	6	118	3	4	126	18	10	371
4-5	26	9	2	26	28	8	116	8	1	166	22	9	421
5-5³⁰	× 6	× 2	× 1	7	1	1	26	3	0	73	13	5	138
9½ hrs.	257	121	21	247	196	65	815	37	28	1100	164	86	3137

Direction of Travel.

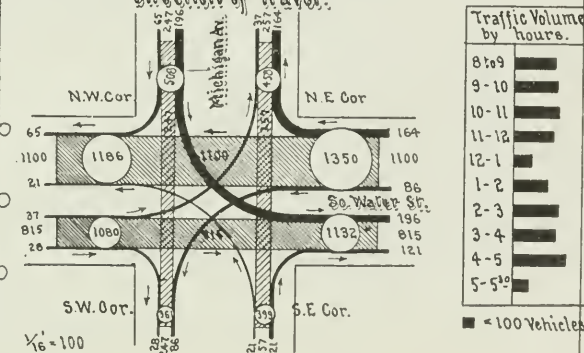
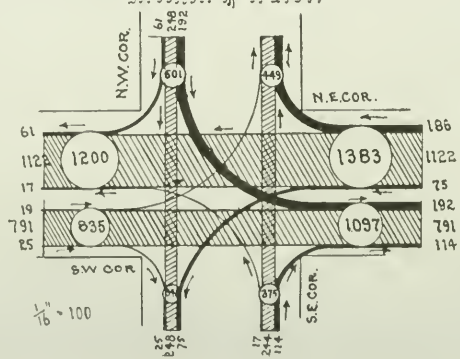


Figure 19

Commercial Traffic Count at So. Water & Mich. Av. 6C
from 8am to 5^{30} pm. July 19th 1916.

Time of observation	S.E. COR. N.	S.E. COR. E.	S.E. COR. W.	N.W. COR. S.	N.W. COR. E.	N.W. COR. W.	S.W. COR. E.	S.W. COR. N.	S.W. COR. S.	N.E. COR. W.	N.E. COR. N.	N.E. COR. S.	Total by hrs
8 to 9	28	16	1	24	12	3	90	1	1	120	15	4	315
9-10	21	13	1	26	18	7	88	1	5	138	16	12	346
10-11	39	20	3	36	20	7	83	2	–	113	21	7	351
11-12	22	13	1	32	19	7	57	2	5	125	15	11	309
12-1	13	4	1	16	6	3	23	1	–	51	11	2	131
1-2	31	14	3	37	18	9	89	4	2	85	8	7	307
2-3	32	12	–	20	26	14	104	2	4	115	28	9	366
3-4	30	14	5	36	43	5	101	2	3	149	29	14	430
4-5	20	8	1	11	26	5	133	–	5	165	30	5	409
$5-5^{30}$	8	0	1	11	4	1	23	4	–	61	13	4	130
$9\frac{1}{2}$ hrs	244	114	17	248	192	61	791	19	25	1122	188	75	3094

Direction of Travel.



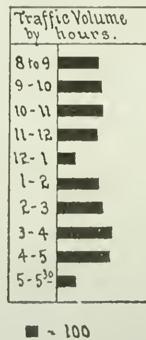
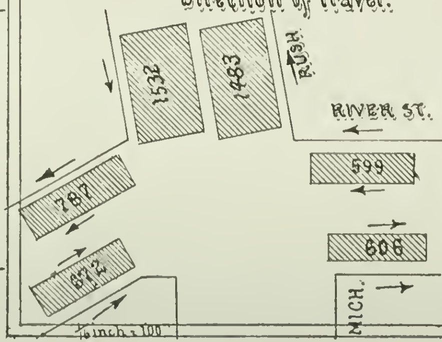


Figure 20

Commercial Traffic Count at River St & Rush Bridge. 7A
from 8 am to 5^{30} pm July 17th 1916.

Time	RIVER ST W of MICH E	RIVER ST W of MICH W	RUSH ST at the Bridge N	RUSH ST at the Bridge S	RIVER ST E of MICH. E	RIVER ST E of MICH. W	Total by hours
8 to 9	68	124	140	160	62	23	577
9-10	89	108	120	149	45	60	571
10-11	67	70	142	220	87	51	627
11-12	67	87	180	145	52	68	599
12-1	46	54	87	78	19	10	294
1-2	53	67	156	180	70	60	586
2-3	70	89	167	180	75	67	648
3-4	75	85	176	180	91	78	685
4-5	92	74	211	200	85	113	775
$6-5^{30}$	55	29	104	40	20	69	317
$9\frac{1}{2}$ hrs	672	787	1483	1532	606	599	5679

Direction of Travel.



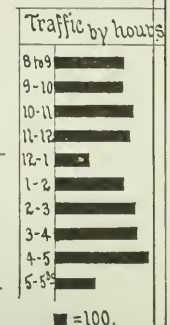


Figure 21

Comercial Traffic Count at River St & Rush St Bridge.
from 8 am to 5³⁰ pm July 18th 1916. **7B**

	RUSH ST BRIDGE		RIVER ST. W. of MICH		RIVER ST. E. of MICH		S.E. COR-MICH			
Time	North	South	E.	W.	E.	W.	N.	E.	W	Total by hours
8 to 9	129	180	55	45	62	42	26	12	2	553
9-10	158	200	39	70	84	54	53	13	–	711
10-11	165	180	92	59	72	69	54	12	–	703
11-12	145	176	93	56	57	54	48	12	–	641
12-1	69	54	22	32	12	15	26	7	–	237
1-2	111	160	34	42	69	45	37	8	–	567
2-3	152	200	104	56	73	92	42	17	–	736
3-4	154	180	37	68	80	88	52	16	–	725
4-5	187	140	90	39	63	75	66	15	–	675
5-5³⁰	76	48	27	16	29	32	32	7	–	267
9½ hrs	1346	1518	743	483	601	566	436	120	2	5815

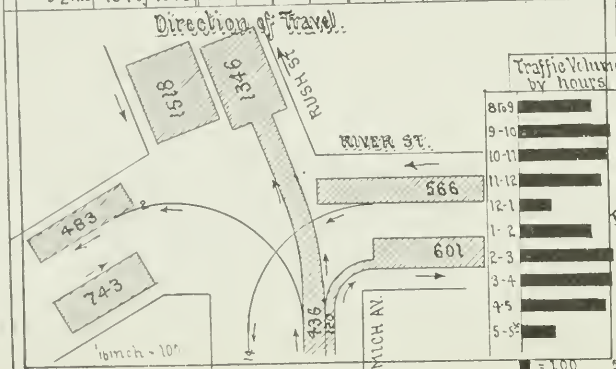


Figure 22

Commercial Traffic Count at River St & Rush Bridge.
from 8 am to 5³⁰ pm July 19th 1916 **7C**

	RIVER ST. W. of MICH		RUSH ST. at the Bridge		RIVER ST. E. of MICH.		
TIME	EAST	WEST	NORTH	SOUTH	EAST	WEST	Total by hours.
8 to 9	78	77	100	180	66	45	546
9-10	89	54	116	144	75	45.	523
10-11	109	63	153	194	57	75	651
11-12	83	45	112	120	50	49	459
12-1	42	39	52	55	29	16	233
1-2	78	59	140	160	68	60	565
2-3	100	60	200	180	65	89	694
3-4	127	65	170	207	93	88	750
4-5	97	58	170	180	80	74	659
5-5³⁰	14	16	70	23	16	44	183
9½ hrs	817	536	1283	1443	599	585	5263

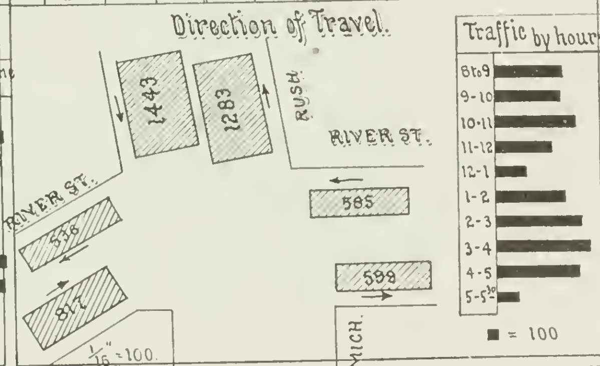


Figure 23

Commercial Traffic Count at Rush & No. Water St. from 8am to 5³⁰ pm July 18th 1916. **8B**

Time of Observation	S.E. COR. N.	S.E. COR. E.	S.E. COR. W.	N.W. COR. S.	N.W. COR. E	N.W. COR. W	BOTH CORNERS
8 to 9	90	20	23	84	4	1	222
9 - 10	149	9	11	104	5	1	279
10 - 11	131	23	36	111	3	5	309
11 - 12	91	18	62	105	–	9	285
12 - 1	49	9	2	28	1	2	91
1 - 2	83	7	33	89	1	2	215
2 - 3	134	29	20	109	4	4	300
3 - 4	147	13	9	100	–	5	274
4 - 5	162	25	29	84	4	1	305
5 - 5³⁰	70	14	12	25	–	–	121
9½ hrs	1106	167	237	839	22	30	2401

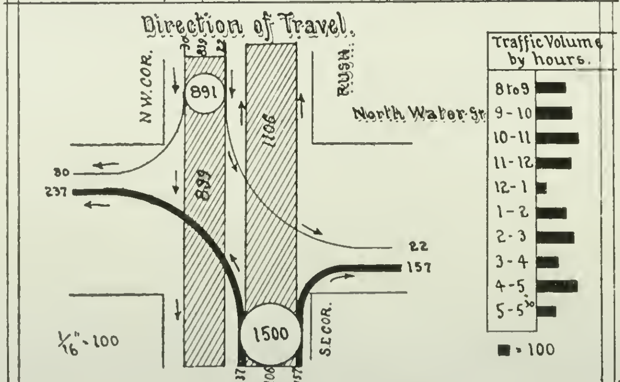


Figure 24

Commercial Traffic Count at Rush & No. Water St. from 8am to 5³⁰ pm. July 19th 1916. **8C**

Time	S.E. COR. N.	S.E. COR. E.	S.E. COR. W.	N.W. COR. S.	N.W. COR. E.	N.W. COR. W.	TOTAL
8 to 9	86	8	26	120	–	–	240
9 - 10	87	23	17	80	–	1	208
10 - 11	142	12	15	84	1	9	263
11 - 12	99	12	30	55	–	4	200
12 - 1	54	4	10	42	–	–	110
1 - 2	108	4	24	71	–	1	208
2 - 3	122	19	50	73	–	4	268
3 - 4	150	18	43	92	3	1	307
4 - 5	143	18	29	65	–	–	255
5 - 5³⁰	72	2	9	11	–	1	95
9½ hrs	1063	120	253	693	4	21	2154

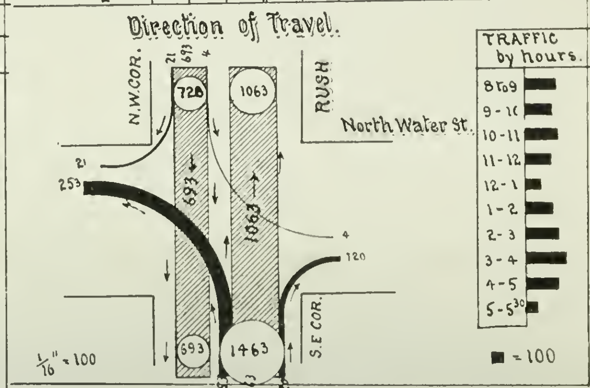


Figure 25

Commercial Traffic Count at Austin & Rush St from 8 am to 5^{30} p.m July 18th 1916. 9B

	S.E COR.			N.W. COR.			S.W. COR			N.E. COR.			All corners
	N.	E.	W.	S.	E.	W.	E.	N.	S.	W.	N.	S.	Total by hrs
8 to 9	44	40	5	27	-	1	60	1	8	50	1	42	279
9-10	61	53	7	39	1	6	68	1	11	66	2	68	383
10-11	59	51	16	47	2	6	59	2	13	54	3	66	378
11-12	40	44	10	42	1	4	60	4	14	66	4	57	346
12-1	19	15	2	28	-	-	25		6	15	1	12	123
1-2	36	45	10	35	1	4	56		13	37	2	49	288
2-3	48	63	14	52	6	3	59	3	24	61	3	56	392
3-4	51	52	12	42	1	7	54	2	12	48	1	63	345
4-5	53	76	18	54	2	3	71	2	9	51	2	47	388
5-5^{30}	19	29	5	6	3	1	41	1	2	29	1	17	154
9½ hrs	430	468	99	372	17	35	553	18	112	477	20	477	3076

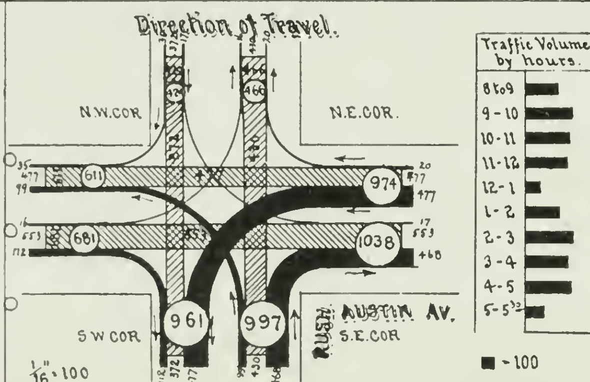


Figure 27

Commercial Traffic Count at Austin & Rush St from 8 am to 5^{30} pm July 19th 1916. 9C

	S.E. COR.			N.W. COR.			S.W. COR.			N.E. COR.			
	N.	E.	W.	S.	E.	W.	E.	N	S.	W.	N.	S.	Total by Hrs
8 to 9	23	46	5	38	-	2	43	2	9	64	1	66	299
9-10	24	61	18	43	2	2	62	4	8	62	2	50	348
10-11	49	40	11	43	2	4	77	1	14	68	-	56	365
11-12	34	21	6	35	1	-	54	—	6	55	1	38	251
12-1	17	9	10	38	1	1	15	1	2	19	2	24	139
1-2	37	51	8	49	2	2	55	-	13	30	2	56	305
2-3	43	37	7	44	1	2	57	1	12	66	5	61	336
3-4	29	56	7	40	2	6	69	2	15	60	1	72	359
4-5	40	55	15	48	—	3	81	1	8	72	1	52	376
5-5^{30}	18	34	10	11	1	1	40	—	—	28	—	9	150
9½ hrs	322	410	97	389	12	23	553	12	87	524	15	484	2928

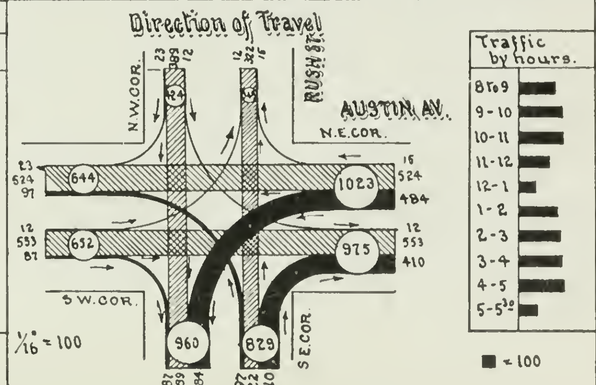


Figure 26

Commercial Traffic Count at Illinois & Rush St.
from 8am to 5^{30} pm July 17th 1916

10A

Time	N.E.COR. W.	N.E.COR. N.	N.E.COR. S.	S.W.COR E.	S.W.COR N.	S.W.COR S.	Total by hours.
8 to 9	53	2	9	55	1	5	125
9-10	53	1	11	56	5	11	137
10-11	59	8	20	43	8	6	144
11-12	38	3	11	44	6	8	110
12-1	18	1	10	32	3	2	66
1-2	29	2	15	30	–	3	79
2-3	32	1	15	33	4	2	87
3-4	42	3	24	42	–	4	115
4-5	39	1	13	75	2	4	134
$5-5^{30}$	22	–	3	39	–	–	64
$9\frac{1}{2}$ hrs	385	22	131	449	29	45	1061

Direction of Travel.

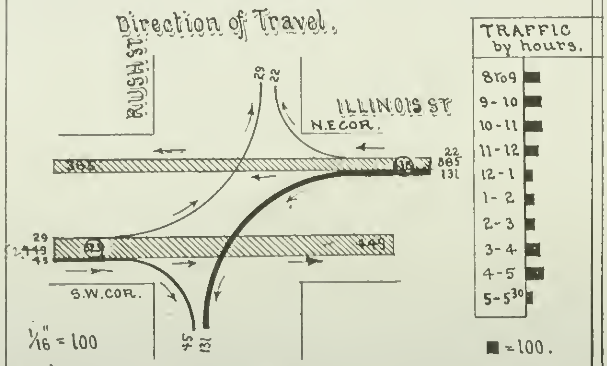


Figure 28

Commercial Traffic Count at Rush & Illinois St.
from 8 am to 5^{30} pm July 18th 1916.

10B

Time	S.E.COR. N.	S.E.COR. E.	S.E.COR. W	N.W.COR. S.	N.W.COR. E.	N.W.COR. W.	S.W.COR. E.	S.W.COR. N.	S.W.COR. S.	N.E.COR. W.	N.E.COR. N.	N.E.COR. S.	Total by hrs.
8 to 9	23	10	4	22	2	2	47	6	6	29	1	15	167
9-10	48	14	10	17	2	2	47	2	7	49	3	13	214
10-11	48	13	5	31	4	1	49	5	7	44	3	14	224
11-12	34	19	2	28	1	–	55	1	1	35	2	17	195
12-1	18	9	3	6	2	2	15	2	2	22	2	8	89
1-2	31	12	3	32	3	1	31	2	3	28	2	15	169
2-3	38	15	7	38	2	2	35	2	8	36	1	15	199
3-4	30	7	15	18	–	1	53	4	5	49	1	7	190
4-5	33	10	6	20	1	1	46	3	4	61	1	16	202
$5-5^{30}$	6	6	1	4	–	–	46	1	–	14	2	2	82
$9\frac{1}{2}$ hrs	309	115	56	216	17	12	424	28	43	367	120	18	1725

Direction of Travel.

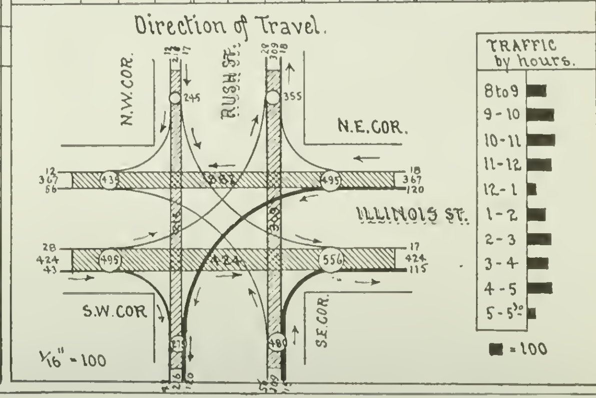


Figure 29

Commercial Traffic Count at Grand Av & Rush St. from 8 am to 5³⁰ pm July 17th 1916 11A

Time of observation	S.E.COR. N.	S.E.COR. E.	S.E.COR. W.	N.W.COR. S.	N.W.COR. E.	N.W.COR. W.	S.W.COR E	S.W.COR N.	S.W.COR S.	N.E.COR. W.	N.E.COR. N.	N.E.COR. S.	Total by hours
8 to 9	15	11	5	23	3	1	52	5	5	33	9	8	170
9-10	34	6	6	14	3	1	74	8	9	57	3	7	222
10-11	25	12	16	23	4	2	67	3	11	53	11	11	238
11-12	24	6	9	17	1	1	65	4	3	54	6	12	202
12-1	16	8	1	20	2	1	39	-	8	36	2	4	137
1-2	25	3	6	24	3	5	44	5	5	49	5	6	180
2-3	25	7	6	16	2	2	48	6	7	62	3	10	194
3-4	31	4	7	17	3	3	67	4	4	52	3	6	201
4-5	25	12	8	20	3	3	57	4	4	57	2	5	200
5-5³⁰	12	1	3	7	3	—	21	1	4	30	2	2	86
9½ hrs	232	70	67	181	27	19	534	40	60	483	46	71	1830

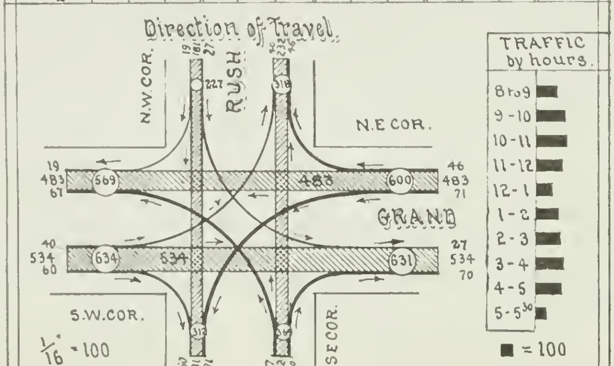


Figure 30

Commercial Traffic Count at Rush & Illinois St. from 8am to 5³⁰ pm July 19th 1916. 10C

Time	S.E.COR N.	S.E.COR E.	S.E.COR W.	N.W.COR. S.	N.W.COR. E.	N.W.COR. W.	S.W.COR E.	S.W.COR N.	S.W.COR S.	N.E.COR. W.	N.E.COR. N.	N.E.COR. S.	Total by hrs
8 to 9	20	10	3	24	4	2	54	5	5	41	3	11	182
9-10	16	13	5	18	2	—	68	4	6	40	1	13	186
10-11	35	10	7	18	-	2	45	1	4	57	3	11	193
11-12	38	14	3	17	-	-	38	4	5	45	3	8	175
12-1	19	9	2	23	-	2	17	1	4	16	1	9	103
1-2	33	11	2	33	1	2	37	4	7	41	4	18	193
2-3	28	12	9	30	1	1	30	-	7	39	2	13	172
3-4	34	18	8	27	-	3	51	3	3	39	1	17	202
4-5	26	17	5	25	-	—	61	5	4	47	-	11	201
5-5³⁰	8	5	.	6	-	1	29	—	1	18	-	1	71
9½ hrs	257	119	44	221	8	13	430	27	46	383	18	112	1678

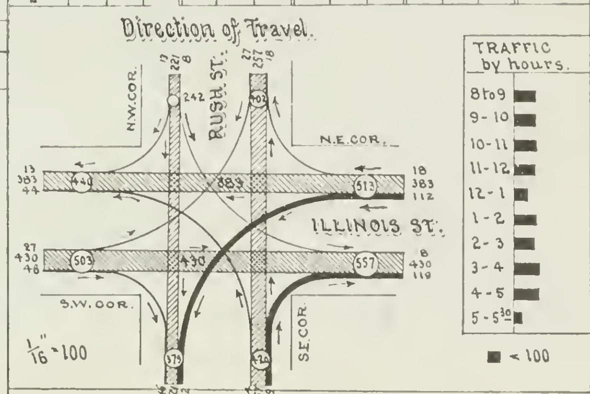


Figure 31

Commercial Traffic Count at Grand Av. & Rush St. from 8 am to 5³⁰ pm. July 18th 1916. (11B)

	S.E. COR. N.	S.E. COR. E.	S.E. COR. W.	N.W. COR. S.	N.W. COR. E.	N.W. COR. W.	S.W. COR. E	S.W. COR. N.	S.W. COR. S.	N.E. COR. W.	N.E. COR. N.	N.E. COR. S.	All Corners Total by hrs
8 to 9	28	8	3	29	1	2	55	6	4	33	10	6	185
9-10	37	7	7	14	3	3	68	2	8	52	6	3	210
10-11	28	12	7	21	4	2	56	6	8	66	2	10	222
11-12	22	8	6	19	3	2	47	5	7	68	5	5	197
12-1	12	4	6	15	2	1	30	2	5	28	4	3	112
1-2	25	3	9	28	1	1	32	3	11	50	1	6	160
2-3	35	6	2	28	2	3	50	4	6	45	2	2	195
3-4	27	2	6	19	3	2	63	1	8	38	8	8	185
4-5	36	5	6	31	6	6	58	7	5	69	4	5	238
5-5³⁰	11	1	2	4	2	—	27	1	4	22	—	1	75
9½ hrs	261	56	54	208	27	22	486	37	66	471	42	49	1779

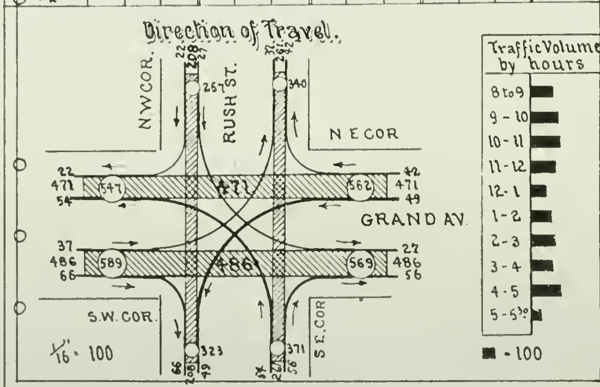


Figure 32

Commercial Traffic Count at Grand Av. & Rush St. from 8 am to 5³⁰ pm. July 19th 1916. (11C)

Time of observation	S.E. COR. N.	S.E. COR. E	S.E. COR. W	N.W. COR. S	N.W. COR. E	N.W. COR. W	S.W. COR. E	S.W. COR. N	S.W. COR. S	N.E. COR. W	N.E. COR. N	N.E. COR. S	All Corners Total by hrs
8 to 9	25	6	1	21	5	1	49	3	8	39	6	5	169
9-10	15	5	3	13	2	1	62	3	6	53	3	3	189
10-11	28	10	5	13	1	6	66	4	4	64	3	7	211
11-12	23	7	7	18	2	2	51	6	5	59	3	2	185
12-1	16	3	3	13	6	1	24	—	7	25	3	13	114
1-2	24	6	4	25	2	—	44	4	10	49	—	3	171
2-3	26	6	5	21	3	1	53	3	4	46	2	5	175
3-4	41	8	4	20	4	1	52	5	3	52	—	11	201
4-5	20	8	9	25	1	2	75	5	6	65	2	1	217
5-5³⁰	13	1	1	13	—	—	20	2	3	23	—	2	78
9½ hrs	231	58	42	182	26	15	496	56	95	475	22	52	1690

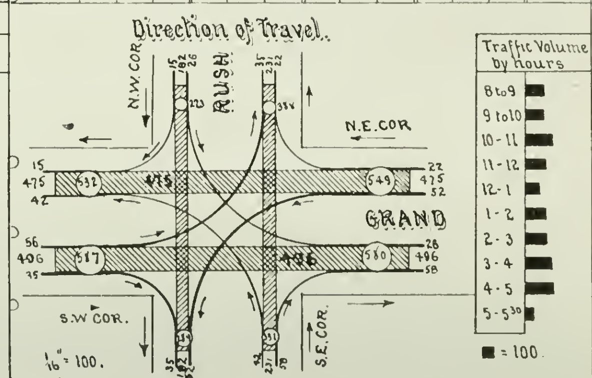
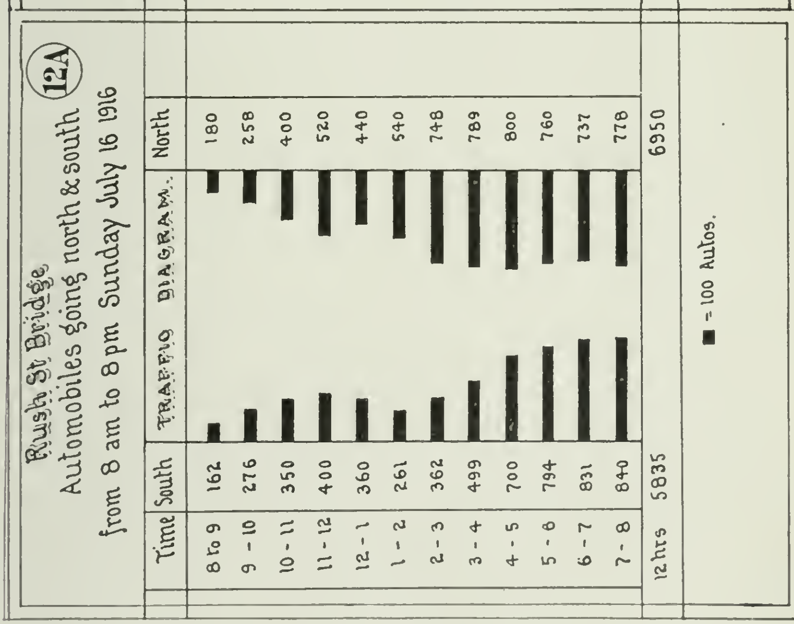
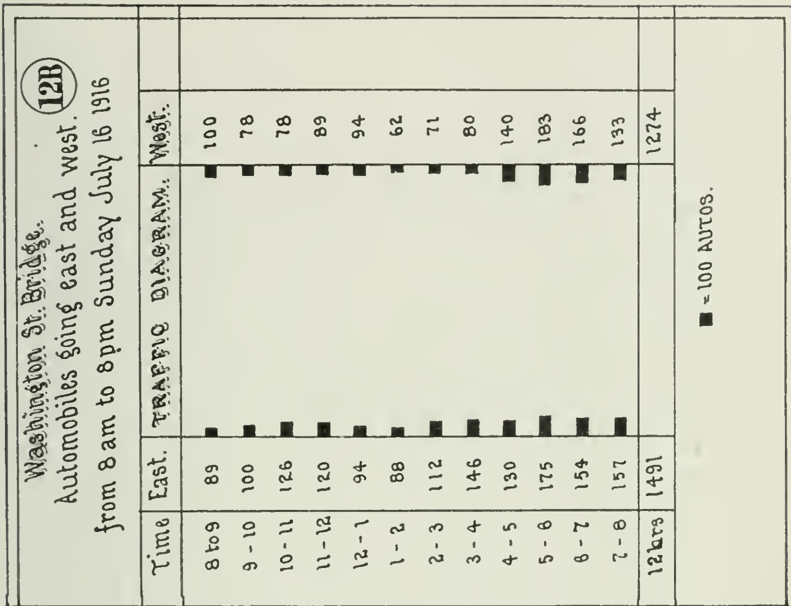


Figure 33



Time	South	North
8 to 9	162	180
9 - 10	276	258
10 - 11	350	400
11 - 12	400	520
12 - 1	360	440
1 - 2	261	540
2 - 3	362	748
3 - 4	499	789
4 - 5	700	800
5 - 6	794	760
6 - 7	831	737
7 - 8	840	778
12 hrs	5835	6950

Figure 34



Time	East.	West.
8 to 9	89	100
9 - 10	100	78
10 - 11	126	78
11 - 12	120	89
12 - 1	94	94
1 - 2	88	62
2 - 3	112	71
3 - 4	146	80
4 - 5	130	140
5 - 6	175	183
6 - 7	154	166
7 - 8	157	133
12 hrs	1491	1274

Figure 35

Jackson Boulevard Bridge. **12C**
Automobiles going east and west
from 8 am to 8 pm Sunday July 16 1916

Time	East.	TRAFFIC DIAGRAM.	West.
8 to 9	140		120
9 - 10	174		176
10 - 11	165		157
11 - 12	220		180
12 - 1	150		192
1 - 2	145		140
2 - 3	220		171
3 - 4	220		160
4 - 5	254		240
5 - 6	234		332
6 - 7	240		296
7 - 8	200		273
12 hrs	2362		2437

■ = 100 Autos

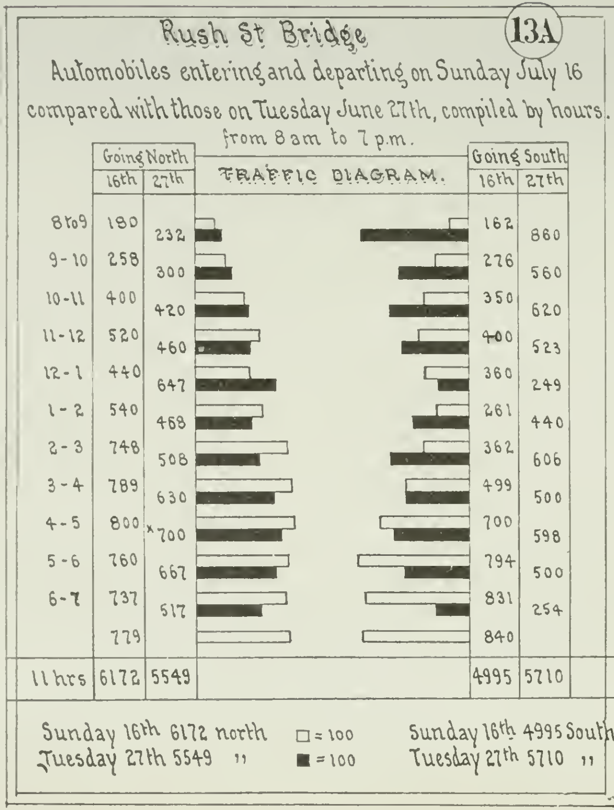
Figure 36

Michigan Av. & 12th. **12D**
Automobiles going north and south.
from 8 am to 8 pm Sunday July 16 1916.

Time	South	TRAFFIC DIAGRAM.	North
8 to 9	209		248
9 - 10	280		342
10 - 11	420		519
11 - 12	511		533
12 - 1	398		519
1 - 2	443		446
2 - 3	431		722
3 - 4	561		747
4 - 5	676		856
5 - 6	860		853
6 - 7	880		584
7 - 8	906		1108
12 hrs	6575		7477

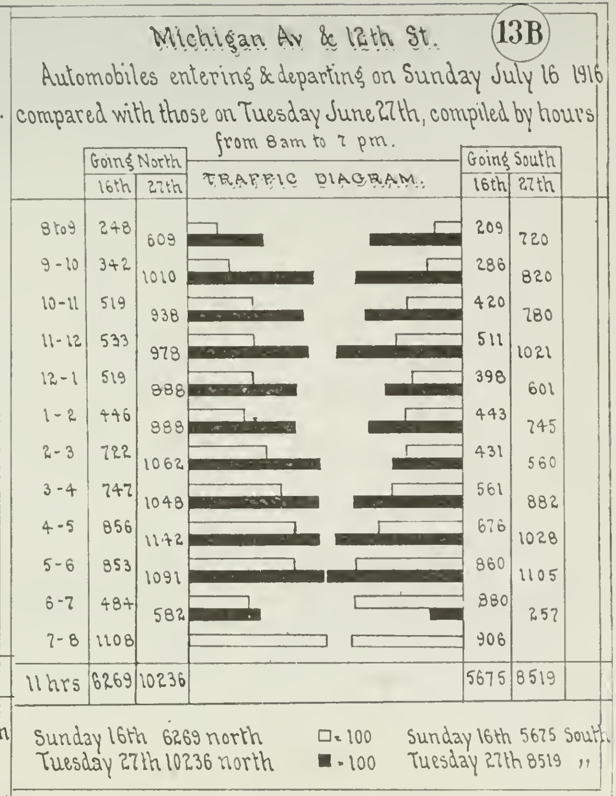
■ = 100 AUTOS.

Figure 37



	Going North 16th	Going North 27th	Going South 16th	Going South 27th
8 to 9	180	232	162	860
9-10	258	300	276	560
10-11	400	420	350	620
11-12	520	460	400	523
12-1	440	647	360	249
1-2	540	468	261	440
2-3	748	508	362	606
3-4	789	630	499	500
4-5	800	×700	700	598
5-6	760	667	794	500
6-7	737	517	831	254
	779		840	
11 hrs	6172	5549	4995	5710

Figure 38



	Going North 16th	Going North 27th	Going South 16th	Going South 27th
8 to 9	248	609	209	720
9-10	342	1010	286	820
10-11	519	938	420	780
11-12	533	978	511	1021
12-1	519	888	398	601
1-2	446	888	443	745
2-3	722	1062	431	560
3-4	747	1048	561	882
4-5	856	1142	676	1028
5-6	853	1091	860	1105
6-7	484	582	880	257
7-8	1108		906	
11 hrs	6269	10236	5675	8519

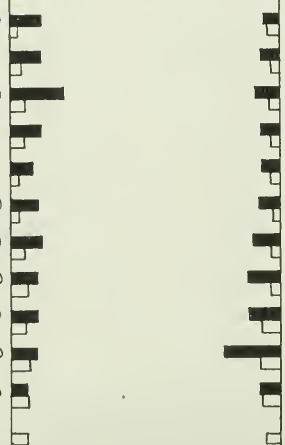
Figure 39

Washington St Bridge 13C

Automobiles entering and departing on Sunday July 16th compared with those of Tuesday June 27th compiled by hours. from 8am to 7pm.

	Going East 16th	Going East 27th	Going West 16th	Going West 27th
8 to 9	89	280	100	120
9-10	100	280	78	160
10-11	126	440	78	200
11-12	120	280	89	159
12-1	94	200	94	140
1-2	88	240	62	180
2-3	112	270	71	210
3-4	146	220	80	270
4-5	130	220	140	260
5-6	175	220	183	460
6-7	154	123	166	173
7-8	157		133	
11 hrs	1334	2773	1141	2332

TRAFFIC DIAGRAM.



Sunday 16th 1334 East ▢ = 100 Sunday 16th 1141 west
Tuesday 27th 2773 East ■ = 100 Tuesday 27th 2332 "

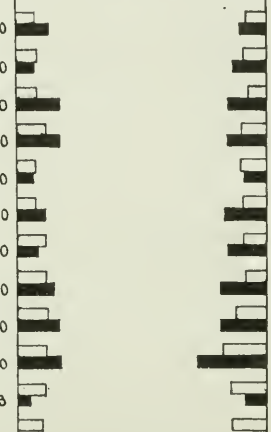
Figure 40

Jackson Blvd Bridge 13D

Automobiles entering and departing on Sunday July 16 compared with those on Tuesday June 27th 1916 compiled by hours from 8am to 7pm.

Time of Observation	Going East 16th	Going East 27th	Going West 16th	Going West 27th
8 to 9	140	360	120	200
9-10	174	140	176	250
10-11	165	340	157	×300
11-12	220	340	180	×300
12-1	150	120	192	180
1-2	145	220	140	317
2-3	220	180	171	300
3-4	220	300	160	360
4-5	254	320	240	360
5-6	234	360	332	540
6-7	240	103	296	153
7-8	200		273	
11 hrs	2162	2783	2164	3260

TRAFFIC DIAGRAM



Sunday 16th 2162 East ▢ = 100 Sunday 16th 2164 West.
Tuesday 27th 2783 East ■ = 100 Tuesday 27th 3260 West.

Figure 41

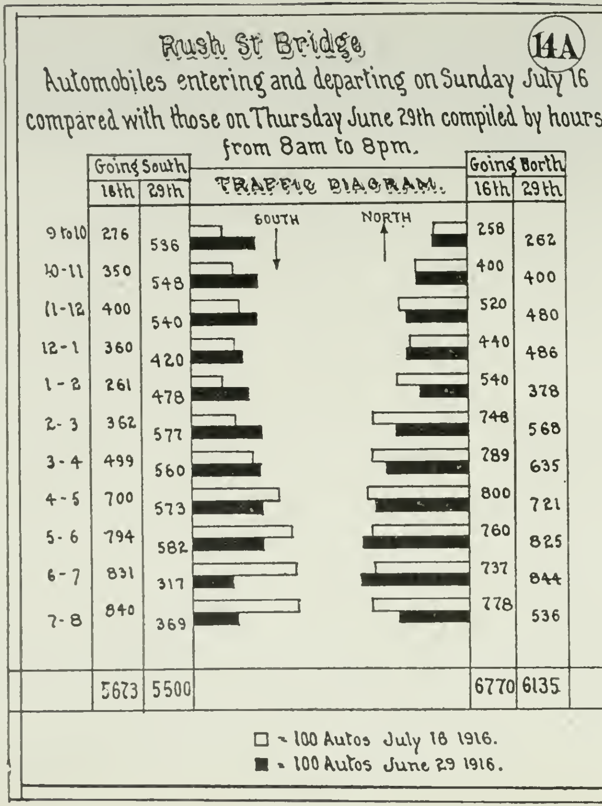


Figure 42

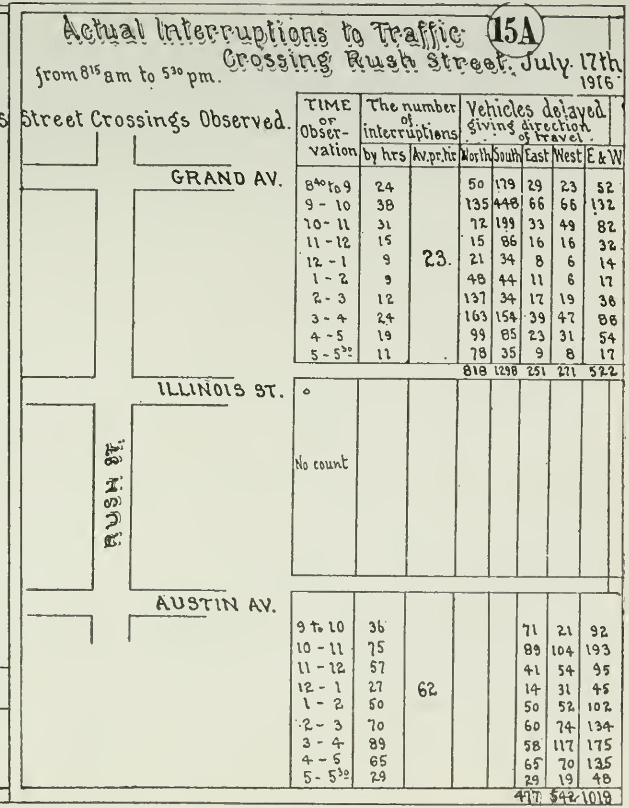


Figure 43

Actual Interruptions to Traffic (15B) Crossing Rush Street, July 18th 1916

from 8^{15} am to 5^{30} p.m.

Street Crossings Observed.	TIME of Obser-vation	The number of Interruptions by hrs	Av. pr hr	Vehicles delayed giving direction of travel North	South	East	West	E.& W.
GRAND AV.	8^{15} to 9	33		32	280	17	28	45
	9 - 10	41		87	300	37	30	67
	10 - 11	39		224	225	54	77	131
	11 - 12	35		93	114	53	56	109
	12 - 1	48	33			35	35	70
	1 - 2	26				34	74	108
	2 - 3	26				41	22	63
	3 - 4	30				36	48	84
	4 - 5	29				67	75	142
	5 - 5^{30}	14				21	25	46
							total	865
ILLINOIS ST.	8^{15} to 9							
	9 - 10							x225
	10 - 11							
	11 - 12							
	12^{15} 1	22				18	27	45
	1 - 2	38				24	35	59
	2 - 3	43	40			39	34	73
	3 - 4	40				33	40	73
	4 - 5	40				31	56	87
	5 - 5^{30}	20				33	18	51
								613
AUSTIN	8^{15} to 9	49				44	89	133
	9 - 10	52				67	142	209
	10 - 11	95				73	142	215
	11 - 12	83				64	123	187
	12 - 1	—				—	—	x100
	1 - 2	49	57			38	57	95
	2 - 3	55				55	68	123
	3 - 4	47				40	48	88
	4 - 5	63				48	68	116
	5 - 5^{30}	26				24	16	40
								1296

RUSH ST.

x estimated.

Figure 44

Actual Interruptions to Traffic (15C) Crossing Rush Street, July 19th

from 8^{15} am to 5^{30} pm.

Street Crossings Observed.	TIME of Obser-vation	The number of interruptions by hrs	Av. pr. hr	Vehicles delayed giving direction of travel North	South	East	West	E.&W.
GRAND AV.	8^{15} to 9	29				41	38	79
	9 - 10	30				40	37	77
	10 - 11^{45}	58				64	69	133
	11^{45} 12^{25}	37 R				43	54	97
	12^{25} 1	12 R	33			9	16	25
	1 - 2	30				38	47	85
	2 - 3	33				49	50	99
	3 - 4	25				30	37	67
	4 - 5	38				54	65	119
	5 - 5^{30}	18				20	17	37
								818
ILLINOIS ST.	8^{15} to 9	31				38	39	77
	9 - 10	40				63	48	111
	10 - 11	35				37	61	98
	11 - 12	28				22	29	51
	12^{15} 1	30 R	39			27	25	52
	1 - 2	56				41	60	101
	2 - 3	37				31	47	78
	3 - 4	42				33	44	77
	4 - 5	44				66	66	132
	5 - 5^{30}	18				13	21	34
								811
AUSTIN AV.	8^{15} to 9	41				34	80	114
	9 - 10	35				42	70	112
	10^{12} 11	32				36	61	97
	11 - 12	31				34	37	71
	12 - 1	11 R				9	16	25
	1 - 2	35	40			35	48	81
	2 - 3	42				40	62	102
	3 - 4	50				44	111	155
	4 - 5	60				77	88	165
	5 - 5^{30}	36				50	31	81
								1003

RUSH ST

R. Rain

Figure 45

16A Actual Interruptions to Traffic July 17 1916
Crossing Michigan Av. from 8²⁰ am to 5³⁰ pm.

Street Crossings Observed.

MICHIGAN AV.

Street	TIME of Observation	The number of actual interruptions: by hours	The number of actual interruptions: Av'rage pr. hr	Actual number of vehicles delayed giving direction of travel: North	South	East	West	E & W
RIVER ST.	8⁴⁰ to 9	—		—		—		
	9 - 10	19°		338°		57		
	10 - 11	1*		35*		2*		
	11 - 12	23+		190+		1		
	12 - 1	53+	54	332+		28		
	1 - 2	56+		450+		77		
	2 - 3	60+		668+		108		
	3 - 4	46°		641°		132		
	4 - 5	58		521		133		
	5 - 5³⁰	30		523		46		
				3775		622		
SOUTH WATER ST.	8²⁰ to 9	45						180
	9 - 10	50						221
	10 - 11	76						205
	11 - 12	73						219
	12 - 1	59	66					112
	1 - 2	64						189
	2 - 3	61						252
	3 - 4	57						333
	4 - 5	61						359
	5 - 5³⁰	37						151
								2227

SUMMARY.

	Interruptions per hour	Vehicles direction
Grand Av.	23	522 E&W.
Austin Av.	62	1019 E&W.
So Water	66	2227 E&W
River St	54	*3775 N

* Bridge open 45 min
° Bridge open 3 times
+ Bridge open 1 time

Figure 46

16B Actual Interruptions to Traffic July 18th. 1916
Crossing Michigan Av. from 8¹⁵ am to 5³⁰ pm.

Street Crossings Observed.

MICHIGAN AV.

Street	TIME of Observation	The number of actual interruptions: by hours	The number of actual interruptions: Av'rage pr. hr.	Actual number of vehicles delayed giving direction of travel: North	South	East	West	E & W
RIVER ST.	8¹⁵ to 9	45		274		61		
	9 - 10	51		557		99		
	10 - 11	55		417		61		
	11 - 12	58		563		59		
	12 - 1	60	56	512		28		
	1 - 2	60		517		85		
	2 - 3	80		736		87		
	3 - 4	50		494		75		
	4 - 5	57		961		106		
	5 - 5³⁰	29		542		41		
				°5573		702		
SOUTH WATER ST.	8¹⁵ to 9	49						181
	9 - 10	64						258
	10 - 11	62						241
	11 - 12	71						236
	12¹⁵ - 1	56	62					102
	1 - 2	63						165
	2 - 3	55						252
	3 - 4	61						337
	4 - 5	64						206
	5 - 5³⁰	37						122
								2100

SUMMARY

	Interruptions per hour	Vehicles direction
Grand Av	33	865 E&W
Illinois St	40	613 E&W
Austin Av	57	1296 E&W
South Water	62	2100 E&W
River St	56	°5573 N.

° Includes 12 bridge openings

Figure 47

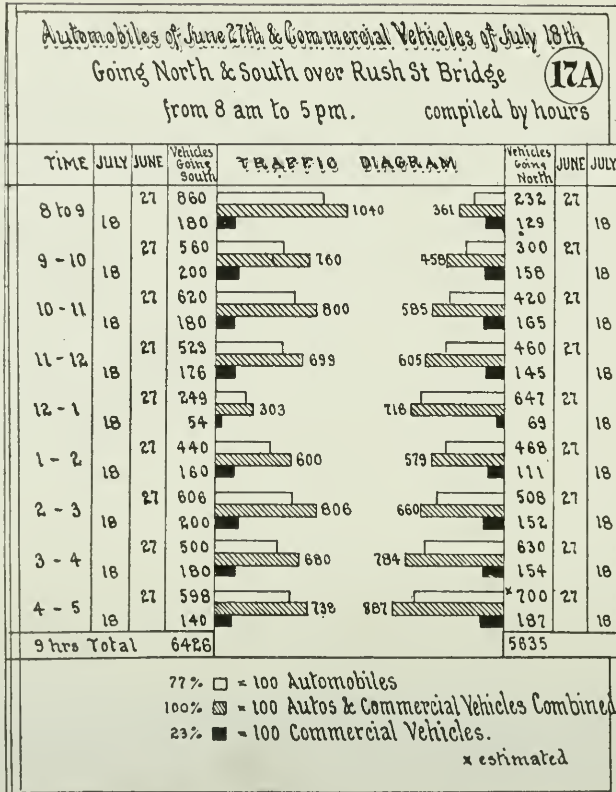


Figure 48

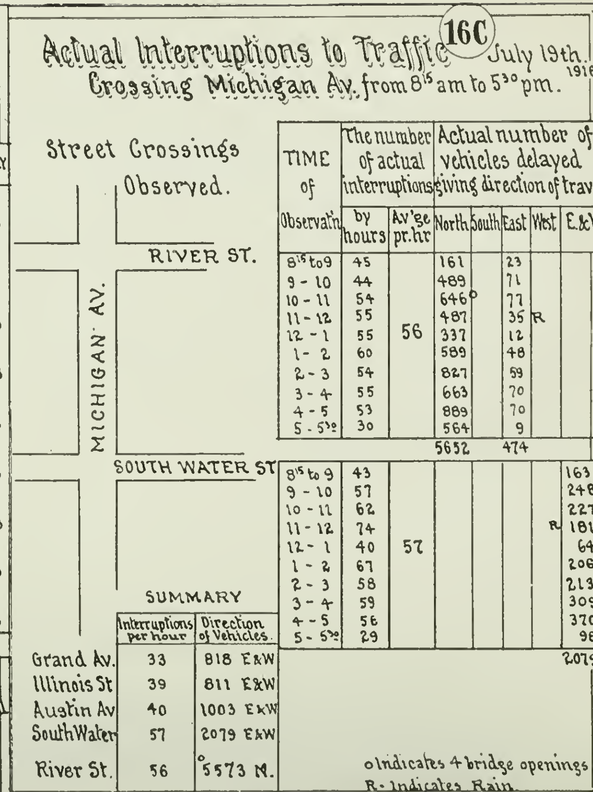
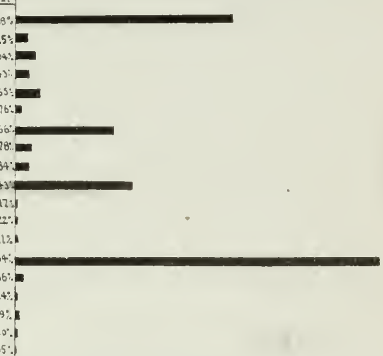


Figure 49

(18A)

Tabulation of Automobiles
Entering and departing from the Loop via Bridges and Streets on Tuesday June 27th 1916
separated into hours from 7am to 7pm.
with a diagramatic and percentage comparison of the traffic volume for each street.

	7 to 8		8 to 9		9 to 10		10 to 11		11 to 12		12 to 1		1 to 2		2 to 3		3 to 4		4 to 5		5 to 6		6 to 7		TOTAL			Percent
	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN & OUT	to Total
Rush	360	120	860	232	560	300	620	420	523	462	249	647	440	468	606	508	500	630	598	*700	500	667	254	517	6070	5669	11739	23.68%
State	2	11	15	9	115	15	13	19	19	21	9	14	16	29	16	18	9	41	16	74	22	80	7	35	259	366	625	1.25%
Dearb.	14	*10	60	*35	16	*38	50	*30	53	*40	47	*45	40	38	48	39	48	29	56	47	56	92	36	57	524	484	1008	2.04%
Clark	15	11	40	29	55	30	35	25	42	46	26	35	*50	55	35	54	26	40	36	46	24	120	24	53	417	535	952	1.43%
Wells	18	19	60	110	81	30	59	48	64	44	75	92	60	60	30	59	22	59	60	60	46	69	26	51	600	710	1310	2.65%
Rand	5	7	6	19	11	23	11	28	19	23	10	12	11	27	17	33	18	*15	13	27	16	19	4	*5	141	237	376	0.76%
Wash	120	60	280	120	280	160	440	200	280	159	200	140	240	180	270	210	220	270	220	260	220	460	123	173	2893	2392	5285	10.66%
Mad	40	20	20	20	30	20	35	40	40	60	14	47	30	40	30	40	35	60	45	40	40	60	41	32	400	479	879	1.78%
Ad'ms	15	20	25	40	20	40	35	40	25	20	23	35	15	35	25	25	18	20	32	20	30	40	26	38	289	373	662	1.34%
Jack'n	20	100	360	200	140	250	340	*300	340	*300	120	180	220	317	180	300	300	360	320	360	360	540	103	153	2803	3360	6163	12.43%
VanB	*1	*1	2	2	0	2	2	6	2	1	4	5	8	6	2	6	7	8	4	6	1	5	3	4	36	52	88	0.17%
Harr.	2	2	4	3	8	7	4	8	2	4	3	5	9	5	4	7	3	1	6	3	8	7	1	1	54	51	105	0.22%
Polk	2	4	1	4	2	–	1	0	5	3	4	1	2	1	2	2	4	4	3	2	2	3	1	2	29	26	55	0.11%
Mich	475	280	609	720	1010	820	938	780	978	1021	889	601	888	748	1062	560	1048	882	1142	1028	1091	1105	582	257	10711	8799	19510	39.34%
Wab	3	4	6	16	14	20	23	25	16	24	15	20	24	35	20	19	16	23	11	17	22	20	13	20	183	243	426	0.86%
State	2	3	4	3	5	0	3	7	7	5	3	–	10	6	7	9	9	6	8	6	6	2	3	4	67	51	118	0.24%
Clark	2	–	4	4	5	8	9	11	8	10	*10	13	11	14	4	13	7	11	7	13	11	17	–	1	78	115	193	0.39%
5th	2	–	4	7	5	3	9	13	6	2	2	1	4	4	3	2	6	2	10	3	2	6	1	3	54	46	100	0.20%
Inda	–	–	–	3	–	2	–	1	–	4	–	–	–	2	–	1	–	3	–	2	–	5	–	2	–	25	25	0.05%
Total	1098	672	2360	1575	2357	1760	2632	1999	2429	2247	1707	1888	2078	2058	2350	1905	2296	2464	2557	2714	2457	3317	1251	1402	25008	24013	49621	100%



each ■ = 1%

1290 Autos have been added to this tabulation as shown at each* so as to make the table statistically complete.
At each* above noted the men employed as counters failed to make complete reports.
By deducting 1290 from 49621 Autos there remains 48331 as the number actually counted.

Figure 50

Automobiles Entering and Departing from the Loop giving percentage of those remaining seperated into hours from 7am. to 7pm. June 27-16

19A

HOURS	ENTERING	DEPARTING	REMAINING	PER CENT REMAINING
7 to 8	1098	672	426	40%
8 to 9	2360	1575	1211	44%
9 to 10	2357	1766	1802	51%
10 to 11	2632	1999	2435	55%
11 to 12	2429	2247	2617	53%
12 to 1	1707	1888	2436	56%
1 to 2	2078	2058	2456	56%
2 to 3	2358	1905	2909	60%
3 to 4	2296	2464	2741	52%
4 to 5	2587	2714	2614	50%
5 to 6	2457	3317	1754	35%
6 to 7	1251	1402	1603	53%
12 hrs	25610	24007	1603	

1603 Autos are in the Loop at 7 p.m

Figure 51

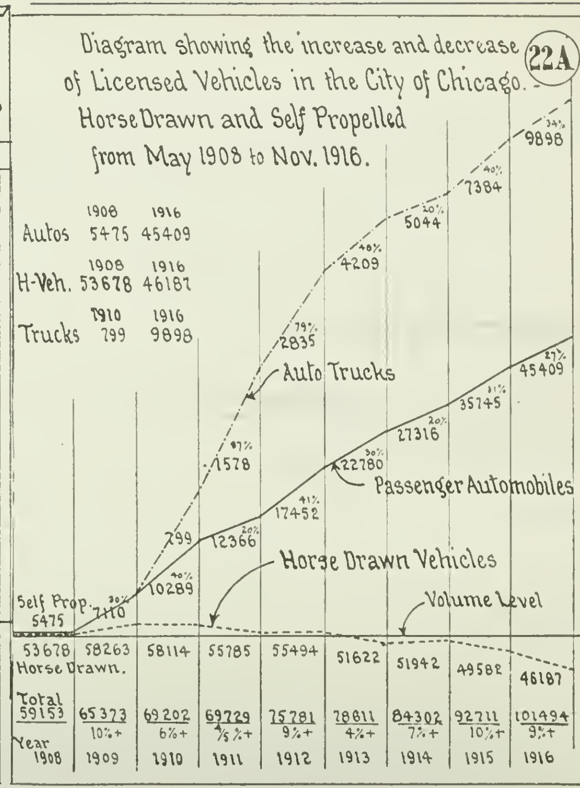


Figure 62

A Comparison of Autos & Passengers stopping at buildings. Giving the total number of machines with the number of persons entering and departing from the building v.s the same machines and persons using Rush St Bridge.

Index No	Observed Locations	Owner of Bld'g.	THURSDAY JUNE 29th: Stopping at the building: Autos	Stopping at the building: Pass	Using Rush St Br.: Autos	Using Rush St Br.: Pass	Per cent Using Bridge: Autos	Per cent Using Bridge: Pass
		WABASH AVE.						
27	139-141 N. Wabash	Cohen Estate	23	39	7	8	30%	21%
28	127-131 N. Wabash	Holmes	20	31	6	11	30%	35%
29	N. E. Cor. Wabash	Garland Bldg.	113	169	47	77	41%	45%
38	N. E. Cor. Randolph	Luther W. Bodman	28	44	9	15	32%	34%
40	S. W. Cor. Madison	Heyworth Bldg.	143	195	44	60	31%	31%
43	222 S. Wabash	A. C. McClurg.	44	61	24	35	54%	57%
Total	Wabash Ave. from Randolph to Adams.		371	539.	137	206	37%	36%
		WABASH AVE.						
31	231-236 S. Wabash	Katherine-S.A.Wells	63	95	17	28	27%	30%
38½	230 S. Wabash	Hartmans	29	39	10	10	36%	27%
39½	238 S. Wabash	Steger Bldg.	39	53	11	14	31%	27%
41	S. W. Cor. Adams	Lyon & Healy	35	53	7	10	20%	19%
32	N. E. Cor. Jackson	Lyon & Healy	70	91	24	31	34%	33%
Total	Wabash Ave. from Adams to Jackson.		236	331	69	93	30%	28%
		WABASH AVE.						
41½	410-416 S. Wabash	Barnheisel	28	50	4	9	15%	18%
42½	N. W. Cor. Congress	Richardson	37	46	8	15	22%	22%
37	601-619 S. Wabash	Ohio Bldg	19	24	5	7	26%	29%
Total	Wabash from Jackson to Harrison.		84	120	17	34	20%	28%
		WABASH AVE.						
34	N. E. Cor. Congress	Auditorium Bldg	177	287	63	102	35%	35%

20B

Figure 53

A Comparison of Autos & Passengers stopping at buildings. Giving the total number of machines with the number of persons entering and departing from the building v.s. the same machines and persons using Rush St

Index No.	Observed Locations	Owner of Bldg	THURSDAY JUNE 29th: Stopping at the Bldg: Autos	Stopping at the Bldg: Pass	Using Rush St Br: Autos	Using Rush St Br: Pass	Per cent using brdg: Autos	Per cent using brdg: Pass
		STATE STREET.						
57	110 N. State	Wm. Borden	91	145	25	38	27%	26%
44	N.E.Cor.Randolph	Masonic Temple	260	518	76	135	30%	26%
45	19 N. State	C. A. Stevens	99	141	29	38	30%	27%
58	S.W.Cor.Washington	Billmans	131	204	27	39	20%	19%
59	N.W.Cor. Madison	Boston Store	143	206	24	34	17%	17%
61	N.W.Cor. Monroe	North American Bldg.	88	143	23	37	26%	26%
Total	State Street from Randolph to Monroe.		812	1355	204	321	25%	24%
		STATE STREET.						
46	101-125 S. State	Palmer Estate	477	667	100	136	21%	20%
47	131 S. State	Browning King	23	37	11	19	48%	51%
48	135-141 S. State	Peacocks	41	48	11	14	27%	30%
53	235 S. State	The Hub	139	193	33	48	24%	25%
Total	State Street from Monroe to Jackson.		680	945	155	217	23%	23%
		STATE STREET						
54	S.E.Cor.Jackson	Leiter Estate	107	150	23	35	21%	23%
55	N.E.Cor.Van Buren	Rothschild & Co.	149	204	22	38	15%	18%
56	Van Buren to Cong.	Siegel Cooper	157	257	20	37	13%	15%
Total	State Street from Jackson to Congress.		413	611	65	110	15%	18%

20C

Figure 54

A Comparison of Autos & Passengers stopping at certain buildings. Giving the total number of machines with the number of persons entering and departing from the building vs the same machines and persons using Rush St Bridge.

Index No.	Observed Locations	Owner of Bld'g	THURSDAY JUNE 29th: Stopping at the building, Autos	Stopping at the building, Pass	Using Rush St Bridge, Autos	Using Rush St Bridge, Pass	Percent using Brdg, Autos	Percent using Brdg, Pass
		DEARBORN STREET.						
62	N.W.Cor. Lake	Cuneo	17	25	3	5	18%	20%
63	180 N. Dearborn	Dickey Bldg.	106	126	11	15	10%	12%
64	14-24 S.Dearborn	Hamilton Club	46	63	17	21	37%	30%
65	S.E.Cor. Lake	Northwestern U.	108	143	12	17	11%	12%
67	35 N.Dearborn	Portland Blk.	11	15	2	2	18%	13%
68	S.E.Cor. Madison	Tribune Bldg.	251	320	47	64	18%	20%
69	35 S. Dearborn	Crilley Bldg.	12	19	2	2	17%	10%
	Dearborn Street from Lake to Monroe		551	711	94	128	17%	17%
		CLARK STREET.						
70	N.E.Cor.Washington	Reaper Block	84	99	15	17	17%	17%
71	127-139 N. Clark-	City Hall Sq. Bldg.	211	487	36	73	17%	15%
73	S.E.Cor. Madison	Morrison Hotel	291	563	51	83	17%	14%
74	N.W.Cor. Jackson	Grand Pacific	206	349	50	70	24%	20%
75	N.W.Cor. Harrison	Rand McNally	52	66	15	21	29%	32%
	Clark Street from Wash. to Harrison.		844	1544	167	264	20%	16%
		LA SALLE STREET						
88	S.E.Cor. Madison	Lbr's. Ex.	63	93	13	20	20%	21%
89	S.E.Cor. Washington	Chamber of Commerce	193	288	21	29	11%	10%
80	S.W. Cor. Madison	Otis Bldg.	85	126	22	30	25%	26%
81	N.W.Cor. Madison	LaSalle Hotel	537	913	139	293	26%	32%
82	S.W.Cor. Wash.	Stock Exchange	175	357	30	50	17%	14%
83	N.W.Cor.Randolph	Metropolitan Blk.	33	47	6	8	18%	19%
87	29 S. LaSalle	National Life	130	170	81	104	60%	60%
	LaSalle St. from Randolph to Madison		1216	1994	312	534	25%	26%
		LA SALLE STREET						
76	S.W.Cor. VanBuren	Rock Island	712	1071	122	224	17%	21%
77	N.W.Cor. " "	Postal Telegraph	63	94	11	16	17%	17%
78	208 S. LaSalle	Continental & Com'l.	352	471	76	98	21%	21%
79	S.W.Cor.Monroe	Woman's Temple	110	143	18	25	16%	17%
85	137 S.La Salle	Home Insurance	43	57	15	22	34%	37%
86	N.W.Cor. Monroe	N. Y. Life	148	183	42	53	29%	29%
	LaSalle St. from Monroe to Van Buren.		1428	2019	289	448	20%	22%

20D

Figure 55

A Comparison of Autos & Passengers stopping at certain buildings. Giving the total number of machines with the number of persons entering and departing therefrom v.s the same machines and persons using Rush St Bridge.

Index No.	Observed Locations	Owner of Bldg	THURSDAY JUNE 29th: Stopping at the Bldg, Autos	Stopping at the Bldg, Pass	Using Rush St Br', Autos	Using Rush St Br', Pass	Percent using Brdg, Autos	Percent using Brdg, Pass
		E. Randolph Street						
93	14-20 E. Randolph	Ryerson	68	85	15	20	22%	23%
		W. Randolph Street						
91	18-20 W. Randolph	Wilson	10	16	2	3	20%	19%
92	58-64 W "	Sears	54	76	14	20	26%	26%
96	20-24 W. "	Simon Reid	17	23	6	6	35%	26%
		Total	81	115	22	29	27%	20%
		W. Madison Street						
98	26 W. Madison	McVickers	52	92	7	17	13%	18%
		W. Monroe Street						
99	111 W. Monroe	Harris Trust	74	98	17	23	23%	23%
100	16 W. Monroe	Majestic	126	284	25	60	20%	21%
		W. Jackson Blvd.						
102	5th Ave. & Jackson	Insurance Exchg.	300	426	66	92	21%	4%
		E. Van Buren Street						
104	64 E. Van Buren	Steinway Hall	31	40	7	9	22%	22%

20E

Figure 56

A comparison of Autos & Passengers stopping at certain buildings Giving the total number of machines with the number of persons entering and departing therefrom v.s. the same machines and persons using Rush St Bridge

Index No	Observed Locations	Owner of Bldg	FRIDAY JUNE 30th					
			Stopping at the building		Using Rush St Bridge		Per cent using br'ge	
			Autos	Pass	Autos	Pass	Autos	Pass
1	18-20 E. Mich. Ave	ard Bldg.	166	208	48	62	29%	30%
2	6 S. Mich. Ave.	Tower Bldg.	84	110	38	58	45%	53%
3	2-8 S. Mich. Ave.	Willoughby Bldg	118	177	45	76	38%	43%
4	24-26 S. Mich. Ave	Edson Keith Co.	126	181	29	46	23%	25%
6	N. W. Cor. Monroe.	University Club.	210	333	101	159	50%	50%
Totel	Michigan Ave. from Washington to Monroe.		704	1009	261	401	37%	40%
5	112 S. Mich. Ave	Ill. Athletic Club	219	330	66	110	30%	33%
7	300-316 S. Mich. Ave	Stratford Hotel	232	414	50	100	21%	24%
8	318 S. Michigan Ave	S. Karpen.	43	56	11	19	26%	33%
9	332 S. Mich. Ave	McCormick Bldg.	270	351	115	164	40%	47%
Total	Michigan Ave. from Monroe to Van Buren.		764	1151	242	393	31%	34%
10	410 S. Michigan Ave	Fine Arts	157	250	59	111	48%	44%
11	422-438 S. Mich. Ave.	Auditorium.	164	265	44	81	27%	30%
12	Cor. Congress St.	Congress Hotel	837	1701	222	445	26%	26%
14	606 S. Mich. Ave	International Harvester	166	239	65	102	40%	47%
15	610-614 S. Mich.	Wm. Blair Estate	17	22	6	10	35%	45%
17	624 S. Mich. Ave	Grant Park Bldg.	65	84	20	29	30%	34%
Total	Michigan Ave. Van Buren to Harrison.		1395	2561	416	778	30%	30%
18	808-814 S. Mich. Ave	H. E. Bucklin	23	33	3	4	13%	12%
19	830 S. Mich. Ave.	Young Woman's C A.	27	41	5	12	15%	29%
20	910 S. Mich. Ave.	Karpen Bldg.	116	171	61	82	52%	48%
21	914-980 S. Mich. Ave	E. J. Lehman Estate	36	50	—	—	—	—
Total	Michigan Ave. Harrison to 10th.		166	245	69	98	41%	40%
22	1006-1012 S. Mich.	E. J. Lehman Estate	38	52	—	—	—	—
24	1136-1138 S. Mich.	Albert W. Shirk	48	69	—	—	—	—
25	1152-1154 S. Mich.	Chas. H. Buddock	60	73	—	—	—	—
Total	Michigan Ave. from 10th to 12th Sts.							
26	101-111 E. 11th. Illinois Central Station.	Ill. Central	458	822	155	303	34%	36%

21A

Figure 57

A comparison of Autos & Passengers stopping at certain buildings. Giving the total number of machines with the number of persons entering and departing therefrom v.s the same machines and persons using Rush St Bridge

Index No	Observed Locations	Owner of Bldg.	FRIDAY JUNE 30th.					
			Stopping at the building		Using Rush St Bridge		Percent using Br'	
			Autos	Pass	Autos	Pass	Autos	Pass.
		WABASH AVE						
27	139-141 N. Wabash	Cohen Estate	24	38	1	4	4%	10%
28	127-131 N. Wabash	Holmes	19	22	—	—	—	—
29	N. E. Cor. Wabash	Garland Bldg.	104	157	51	71	50%	45%
38	N. E. Cor. Randolph	Luther W. Bodman	32	51	19	29	60%	57%
40	S. W. Cor. Madison	Heyworth Bldg.	185	247	55	80	30%	32%
43	222 S. Wabash	A. C. McClurg.	89	157	26	45	30%	29%
Total	Wabash Ave. from Randolph to Adams.		434	650	152	229	35%	35%
		WABASH AVE.						
31	231-236 S. Wabash	Katherine-S.A.Wells	60	70	13	13	21%	18%
38½	230 S. Wabash	Hartmans	15	22	5	12	33%	54%
39½	238 S. Wabash	Steger Bldg.	19	29	—	—	—	—
41	S. W. Cor. Adams	Lyon & Healy	26	37	7	10	27%	27%
32	N. E. Cor. Jackson	Lyon & Healy	33	44	12	15	36%	34%
Total	Wabash Ave. from Adams to Jackson.		134	173	37	50	27%	29%
		WABASH AVE.						
41½	410-416 S. Wabash	Barnheiser	19	36	—	—	—	—
42½	N. W. Cor. Congress	Richardson	46	65	5	7	11%	11%
37	501-619 S. Wabash	Ohio Bldg	24	32	5	7	21%	22%
Total	Wabash from Jackson to Harrison.		70	97	10	14	13%	14%
		WABASH AVE.						
36	N. E. Cor. Congress	Auditorium Bldg	119	174	43	73	36%	42%

21B

Figure 58

A comparison of Autos & Passengers stopping at certain buildings, giving the total-number of machines with the number of persons entering and departing therefrom v.s the same machines and persons using Rush St Bridge.

Index No.	Observed Locations	Owner of Bldg	FRIDAY JUNE 30th — Stopping at the Building: Autos	Pass	Using Rush St Bridge: Autos	Pass	Per cent using bridge: Autos	Pass
		STATE STREET.						
57	110 N. State	Wm. Borden	110	184	43	71	40%	40%
44	N.E.Cor.Randolph	Masonic Temple	304	631	84	167	28%	26%
45	19 N. State	C. .. Stevens	110	169	33	49	30%	30%
58	S.W.Cor.Washington	Hillmans	131	176	21	27	16%	15%
59	N.W.Cor. Madison	Boston Store	145	217	24	48	17%	22%
61	N...Cor. Monroe	North American Bldg	86	128	17	32	20%	25%
Total	State Street from Randolph to Monroe.		885	1503	222	394	24%	26%
		STATE STREET.						
46	101-125 S. State	Palmer Estate	420	628	103	156	24%	24%
47	151 S. State	Browning King	26	32	6	6	23%	19%
48	135-141 S. State	Peacocks	23	28	11	13	48%	45%
53	235 S. State	The Hub	185	281	13	18	8%	6%
Total	State Street from Monroe to Jackson.		654	969	133	193	20%	20%
		STATE STREET						
54	S.E.Cor.Jackson	Leiter Estate	106	146	12	18	12%	12%
55	N. .Cor.Van Buren	Rothschild & Co.	189	349	32	46	17%	13%
56	Van Buren to Cong.	Siegel Cooper	214	329	39	55	18%	17%
Total	State Street from Jackson to Congress.		509	824	83	119	16%	14%

21C

Figure 59

A comparison of Autos & Passengers stopping at certain buildings. Giving the total number of machines with the number of persons entering and departing therefrom v.s the same machines and persons using Rush St Bridge.

Index No.	Observed Locations	Owner of Bldg.	FRIDAY JUNE 30 1916 — Stopping at the Building: Autos	Pass	Using Rush St Bridge: Autos	Pass	Per cent Using Bridge: Autos	Pass
		DEARBORN STREET.						
62	N.W.Cor. Lake	Cuneo	26	36	3	5	11%	14%
63	180 N. Dearborn	Dickey Bldg.	112	153	6	7	5%	5%
64	14-24 S.Dearborn	Hamilton Club	40	54	13	21	32%	39%
65	S.E.Cor. Lake "	Northwestern U.	120	160	10	11	8%	7%
67	35 N/Dearborn	Portland Blk.	29	40	—	—	—	—
68	S.E.Cor. Madison	Tribune Bldg.	152	193	31	36	20%	18%
69	35 S. Dearborn	Crilley Bldg.	17	30	—	—	—	—
	Dearborn Street from Lake to Monroe		450	596	63	80	14%	13%
		CLARK STREETS.						
70	N.E.Cor.Washington	Reaper Block	122	141	17	21	14%	14%
71	127-139 N. Clark-	City Hall Sq. Bldg.	154	352	40	101	26%	28%
73	S.E.Cor. Madison	Morrison Hotel	207	347	38	69	18%	14%
74	N.W.Cor. Jackson	Grand Pacific	208	402	—	—	—	—
75	..Cor. Harrison	Rand McNally	78	97	54	91	70	93%
	Clark Street from Wash. to Harrison.		561	937	149	282	26	30%
		La Salle Street						
88	S.E.Cor. Madison	~~Stimx Bldg~~ Lbr's Ex.	74	101	15	19	20%	19%
89	S.E.Cor. Washington	Chamber of Commerce	225	283	35	21	15%	8%
80	S.W. Cor. Madison	Otis Bldg	72	109	14	30	20%	29%
81	N.W.Cor. Madison	LaSalle Hotel	470	807	126	247	27%	30%
82	S.W.Cor. ..ach	Stock Exchange	190	247	29	39	15%	15%
83	N.W.Cor Randolph	Metropolitan Blk.	36	49	4	4	11%	8%
87	29 S. LaSalle	National Life	81	104	22	34	27%	32%
	LaSalle St. from Randolph to Madison		1148	1700	245	394	21%	23%
		LA SALLE STREET						
76	S.W.Cor. VanBuren	Rock Island	553	1009	139	273	25%	26%
77	N.W.Cor " "	Postal Telegraph	107	168	18	25	15%	15%
78	208 S. LaSalle	Continental & Com'l	401	527	101	128	25%	24%
79	S.W.Cor Monroe	Woman's Temple	70	78	15	15	21%	20%
85	137 S.La Salle	Home Insurance	32	36	8	9	25%	25%
86	N.W.Cor. Monroe	N. Y. Life	117	142	29	31	25%	22%
	LaSalle St. from Monroe to Van Buren.		1280	1960	308	481	24%	24%

21D

Figure 60

A Comparison of Autos & Passengers stopping at certain buildings. Giving the total number of machines with the number of persons entering and departing from the building, vs the same machines and persons using Rush St Bridge

INDEX No.	Location	Buildings Observed	Thursday June 29-16 Stopping at the bldg AUTOS	PASS	Using Rush St Brge AUTOS	PASS	Percentage using Brge AUTOS	PASS
1	18-20 N. Mich. Ave.	Ward Bldg.	155	199	41	48	27%	24%
2	6 N. Mich. Ave.	Tower Bldg.	68	89	26	34	38%	38%
3	2-8 S. Mich. Ave.	Willoughby Bldg.	61	83	34	45	55%	54%
4	24-26 S. Mich. Ave.	Edson Keith Co.	111	187	31	42	28%	22%
5	N. W. Cor. Monroe.	University Club.	190	273	89	118	47%	43%
Total	Michigan Ave. from	Washington to Monroe.	585	831	221	287	38%	34%
6	112 S. Mich. Ave	Ill. Athletic Club.	227	334	61	84	22%	25%
7	300-316 S. Mich. Ave.	Stratford Hotel	254	463	50	101	20%	24%
8	318 S. Michigan Ave.	S. Karpen.	47	63	7	11	15%	17%
9	332 S. Mich. Ave	McCormick Bldg.	291	395	104	143	35%	36%
Total	Michigan Ave. from	Monroe to Van Buren.	819	1255	222	339	27%	27%
10	410 S. Michigan Ave.	Fine Arts	160	248	63	88	40%	35%
11	422-438 S. Mich. Ave.	Auditorium.	173	302	39	60	22%	20%
12	Cor. Congress St.	Congress Hotel	869	1613	196	351	22%	21%
14	606 S. Mich. Ave	International Harvester	70	97	21	41	30%	42%
16	610-614 S. Mich.	Wm. Blair Estate	41	59	12	17	30%	30%
17	624 S. Mich. Ave	Grant Park Bldg.	65	87	18	19	28%	22%
Total	Michigan Ave. Van Buren to Harrison.		1378	2406	349	576	25%	24%
18	802-814 S. Mich. Ave.	H. E. Bucklin	14	21	6	9	43%	43%
19	830 S. Mich. Ave.	Young Woman's C. A.	49	71	6	9	13%	12%
20	910 S. Mich. Ave.	Karpen Bldg.	130	186	32	41	25%	22%
21	914-908 S. Mich. Ave	E. J. Lehman Estate	40	54	6	7	15%	13%
Total	Michigan Ave. Harrison to 10th.		233	332	50	66	21%	20%
22	1006-1012 S. Mich.	E. J. Lehman Estate	32	46	5	—	17%	—
24	1136-1138 S. Mich.	Albert W. Shirk	70	91	5	15	7%	15%
25	1152-1164 S. Mich.	Chas. H. Ruddock	73	89	15	17	20%	20%
Total	Michigan Ave. from	10th to 12th Sts.	175	226	25	--	14%	—
26	1 1-111 E. 11th. Illinois Central Station.	Ill. Central	431	815	123	241	28%	29%

20A

Figure 52

A comparison of Autos & Passengers stopping at certain buildings. Giving the total number of machines with the number of persons entering and departing therefrom v.s. the same machines and persons using Rush St Bridge.

Index No.	Observed Locations	Owner of Bldg.	FRIDAY JUNE 30th Stopping at the building Autos	Pass	Using Rush St Bridge Autos	Pass	Per cent using Brge Autos	Pass
		E. Randolph Street						
93	14-20 E. Randolph	Ryerson	43	53	14	20	32%	38%
94	22-36 E "	L. McCormick	35	44	6	10	17%	22%
		W. Randolph Street						
91	18-20 W. Randolph	Wilson	4	4	3	4	75%	100%
92	58-64 W. "	Sears	54	69	17	20	31%	30%
96	20-24 W. "	Simon Reid	16	21	5	11	31%	52%
95	69 W. "	Chicago Title & Trust.	69	86	17	24	25%	28%
		W. Madison Street						
98	25 W. Madison	McVickers	41	83	7	16	17%	19%
		W. Monroe Street						
99	111 W. Monroe	Harris Trust	71	85	20	26	28%	30%
100	16 W. Monroe	Majestic	117	273	34	78	29%	28%
		W. Jackson Blvd.						
102	5th Ave. & Jackson	Insurance Exchg.	291	404	51	66	17%	14%
		E. Van Buren Street						
104	64 E. Van Buren	Steinway Hall	24	25	10	13	41%	52%

21E

Figure 61

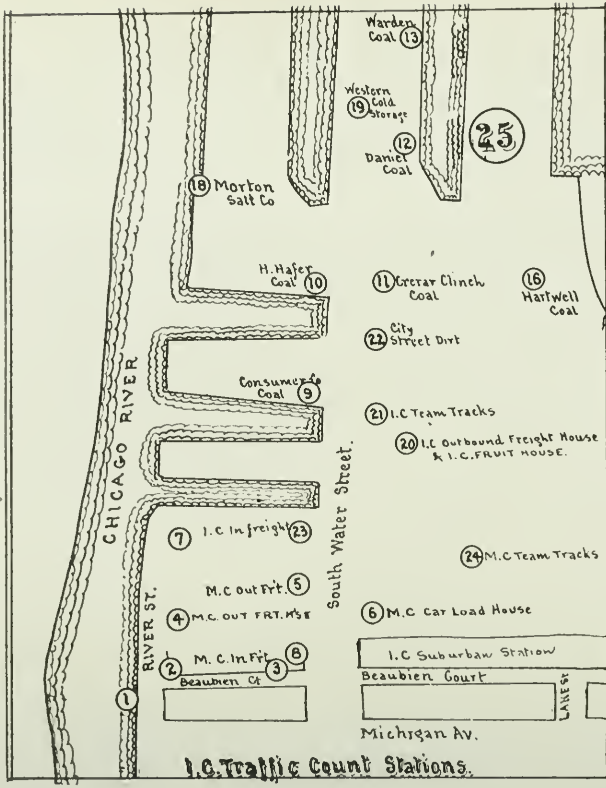


Figure 63

I.C. Traffic Count. 49 B

Station 8 at Cor of Beaubien Ct & So. Water St.

	NORTH ON BEAUBIEN TURNING EAST ON SOUTH WATER.	WEST ON SO. WATER TURNING SOUTH ON BEAUBIEN CT.
7 & 8	81	9
8-9	103	45
9-10	145	61
10-11	140	60
11-12	91	84
12-1	51	21
1-2	109	40
2-3	118	26
3-4	149	65
4-5	124	57
5-6	45	17
Total	1156	485

Includes all vehicles loaded or empty

East counted by F. L. Graybill Feb 21 1917.
West counted by A. F. Angelmeyer

Figure 64

I.C. R.R. TRAFFIC COUNT. (26 A)

Station 1 at River St bet Mich. Av & Beaubien Ct.

Counted by Paul Grossman. Feb 20 1917.

	Vehicles going East			Vehicles going West			East & West	Diagram
Time	Horse	Auto	Empty	Horse	Auto	Empty	Total	
8 to 9	36	6	29	23	7	25	126	
9-10	24	12	31	22	11	19	119	
10-11	37	11	16	30	14	30	138	
11-12	20	13	20	29	17	40	139	
12-1	9	3	4	5	0	4	24	
1-2	33	13	18	18	10	33	125	
2-3	37	7	29	36	13	46	168	
3-4	47	8	18	32	12	32	149	
4-5	42	14	11	32	15	38	152	
9 hrs.	284	87	176	227	99	267	1140	

Vehicles going east 547
Vehicles going west 593
Both directions 1140

26% of all vehicles were Auto Trucks.

Figure 65

I.C. TRAFFIC COUNT. (26 B)

On River St bet Beaubien Ct & Michigan Av.

Station 1

Counted by Paul Grossman Feb 21 1917

	Vehicles going East			Vehicles going West.			
	LOADED		Empty	LOADED		Empty	East-West
	Horse	Auto	Both	Horse	Auto	Both.	Total
7 to 8	18	4	67	6	0	8	103
8-9	37	11	36	18	5	16	123
9-10	29	12	21	17	12	24	115
10-11	23	4	31	42	10	31	141
11-12	29	7	23	32	10	28	129
12-1	13	2	9	12	1	8	45
1-2	33	14	24	36	6	21	134
2-3	47	6	21	24	7	32	137
3-4	46	15	19	40	14	42	176
4-5	42	12	6	30	5	44	139
5-6	17	3	5	18	8	68	119
Total	334	90	262	275	78	322	1361

Vehicles going east 686
Vehicles going west 675
Total 1361

22% of all were Auto Trucks.

Figure 66

27 A

I. C. Traffic Count.

Station 2 at north end of the in-freight M.C. house

Vehicles using Beaubien Ct via River St.

Counted by J. L. Handelman Feb 20 1917

	Vehicles to River St			Vehicles from River St			
	Loaded		Empty	Loaded		Empty	
Time	Horse	Auto	Both	Horse	Auto	Both	Total
8 to 9	3	1	9	3	0	7	23
9-10	5	0	3	2	0	12	22
10-11	11	1	7	3	0	15	37
11-12	9	4	6	6	0	18	43
12-1	3	0	0	0	0	0	3
1-2	4	7	5	5	3	9	33
2-3	11	1	7	2	0	14	35
3-4	16	2	8	5	0	9	40
4-5	31	0	11	3	1	22	68
Total	93	16	56	29	4	106	304

Loads going north to River St 109
Empties " " " " " 56
Loads coming south from River St 33
Empties " " " " " 106
Total 304

Figure 67

27 B

I. C. TRAFFIC COUNT.

Traffic at M.C. Inbound Freight House

Station 2 Using River St.

Counted by J. L. Handelman Feb. 21 1917

	Departing from Inbound House			
	LOADED		Empty	Total
Time	Horse	Autos	Both	Loads
7 to 8	1	0	0	1
8-9	4	0	3	4
9-10	15	0	4	15
10-11	13	0	6	13
11-12	10	2	4	12
12-1	4	2	0	6
1-2	13	0	3	13
2-3	15	0	10	15
3-4	16	1	9	17
4-5	21	1	7	22
5-6	15	0	22	15
Total	127	6	68	133

133 vehicles with frt. from M.C. crossed Mich Av. at River St.
68 empty vehicles from Beaubien Ct crossed Mich Av at River St.
5% were Auto Trucks.

Figure 68

I.C.R.R. Traffic Count.
at Mich Cent In Freight House

28 A

Station 3 Located at S-W. End of M.C. In Freight House

Counted by W. Thiele Tuesday Feb 20 1917.

	Empty from Mich Av to H'se		Departing Loaded		from So Water going north		
Time	Horse	Autos	Horse	Autos	Horse	Autos	Total
8 to 9	22	7	32	6	0	0	67
9-10	22	6	30	2	6	1	67
10-11	26	5	32	3	9	0	75
11-12	27	9	30	4	3	3	76
12-1	3	0	13	1	2	0	19
1-2	18	8	14	1	7	1	49
2-3	19	6	20	8	8	0	61
3-4	23	4	25	9	4	1	66
4-5	21	4	26	3	20	3	77
9 hrs	181	49	222	37	59	9	557

Vehicles coming from Mich Av via So Water for loading at house 230

Loaded vehicles departing from house going to Mich Av. 259

Vehicles coming from east So Water going to house 68

total 557

17% of the commercial vehicles are Auto Trucks.

Figure 69

I.C. TRAFFIC COUNT.

28 B

Traffic from M.C. Inbound L.C.L. House

Station 3 located at south end of M.C. infrt house.

Counted by W. Thiele Wednesday Feb 21 1917.

	GOING NORTH Empty from Mich		COMING SOUTH Loaded		GOING NORTH from E So Water		Total
Time	Horse	Auto	Horse	Auto	Horse	Auto	
7 to 8	21	1	4	1	1	0	28
8-9	28	5	21	3	1	1	59
9-10	33	10	23	4	4	0	74
10-11	30	1	30	0	6	1	68
11-12	23	3	33	1	3	1	64
12-1	9	2	9	0	2	0	22
1-2	20	2	26	1	6	4	59
2-3	25	4	30	5	7	1	72
3-4	24	8	28	14	16	3	93
4-5	23	4	20	5	15	4	71
5-6	8	0	23	0	10	0	41
11 hrs	244	40	247	34	71	15	651

284 empty vehicles from Michigan Av

281 loaded vehicles departed for Mich Av

86 partly loaded veh. came from east So. Water St for additional load, taken on at M.C. House.

14% were Auto Trucks.

Figure 70

I.C. TRAFFIC COUNT. (29 A)

at the Mich Central out freight house.

Station 4 located at the north end of M.C. Out H'se

Counted by A: Touff Feb 20 1917

	Vehicles going south				Vehicles going north				Total
	Horse V.		Auto Tr.		Horse V.		Auto Tr.		
Time	Load	Emty	Load	Mty	Load	Mty	Load	Mty	Total
8 to 9	25	3	2	1	4	15	1	1	52
9-10	20	5	4	2	2	14	4	1	52
10-11	28	3	3	0	3	16	1	4	58
11-12	28	2	2	1	2	29	0	5	69
12-1	6	0	2	0	0	0	0	1	9
1-2	18	2	5	0	0	18	0	3	46
2-3	21	1	3	0	0	18	0	4	47
3-4	35	1	4	0	1	19	0	1	61
4-5	22	0	3	0	1	30	0	3	59
Total	203	17	28	4	13	159	6	23	453

Arriving at freight house via River St 252

Departing from frt. house via River St. 201

Figure 71

I.C. TRAFFIC COUNT. (29 B)

at M.C. Out Freight House using River St

Station 4

Counted by A. Touff. Feb 21 1917

	Arriving at house		Going north to River		Total	
	LOADED		LOADED		to house	to River St
Time	Horse	Auto	Horse	Auto		
7 to 8	5	1	4	0	6	4
8-9	18	5	12	3	23	15
9-10	21	2	17	6	23	23
10-11	25	4	20	3	29	23
11-12	21	3	22	1	24	23
12-1	4	2	6	1	6	7
1-2	22	5	11	4	27	15
2-3	29	2	29	5	31	34
3-4	41	4	38	4	45	42
4-5	28	3	26	1	31	27
5-6	6	0	20	4	6	24
Total	220	31	205	32	251	237

251 Loads arrived at M.C. out house via River St.

237 Loads came north and crossed Mich Av at River St

13% were Auto Trucks.

Figure 72

I.C. TRAFFIC COUNT. (30 A)

Station 5 located at south end of M.C out house
Traffic to and from M.C out freight house.

Counted by Sam Katzin Tuesday Feb 20 1917

	Arriving at house		Departing from House		
	LOADED		EMPTY		
Time	Horse	Auto	Horse	Empty	Total
8 to 9	30	4	31	2	67
9-10	27	2	31	3	63
10-11	40	3	33	2	78
11-12	40	5	25	4	74
12-1	6	1	4	1	12
1-2	41	2	37	1	81
2-3	42	3	29	2	76
3-4	78	13	56	10	157
4-5	65	10	50	11	136
Total	369	43	296	36	744

Total vehicles arriving at freight house 412
Total vehicles departing from freight house 332

Figure 73

I.C TRAFFIC COUNT. (30 B)

at M.C L.C.L. Out Freight House.
Station 5 at South End of M.C Out Frt House
Counted by Sam Katzen Feb 21 1917

Time	Arriving at House LOADED Horse	Autos	Departing from House EMPTY Horse	Auto	Total Loads	Empty
7 to 8	10	1	14	1	11	15
8-9	21	4	26	2	35	28
9-10	31	4	33	3	35	36
10-11	39	3	30	3	42	33
11-12	10	1	18	3	11	21
12-1	8	2	6	1	10	7
1-2	40	2	33	2	42	35
2-3	63	10	65	6	73	71
3-4	69	5	58	5	74	63
4-5	85	8	71	12	93	83
5-6	3	2	24	3	5	27
Total	389	42	378	41	431	419

431 Vehicles brought loads
10% were Auto Trucks

Figure 74

I.C. Traffic Count. 31 A

Station 6 at north end of M.C. CarLoad in frt. house traffic to and from M.C in frt C/L house.

Counted by Frank Katzin Tuesday Feb 20 1917.

	Vehicles going south		Vehicles coming north			Diagram.
	Arriving Empty		Departing Loaded		Total	
Time	Horse	Auto	Horse	Auto		
8 to 9	35	3	19	1	58	
9 - 10	33	2	32	2	69	
10 - 11	29	1	44	1	75	
11 - 12	17	1	21	0	39	
12 - 1	8	0	6	0	14	
1 - 2	22	0	28	0	50	
2 - 3	28	0	27	0	55	
3 - 4	62	1	41	0	104	
4 - 5	45	2	55	3	105	
9 hrs	279	10	273	7	569	

Total vehicles arriving at the freight house 289

Total, vehicles departing from the frt. house 280

Figure 75

I.C. TRAFFIC COUNT. 31 B

of Traffic to and from M.C. CarLoad In Freight H'se

Station 6

Counted by Frank Katzen Feb 21 1917.

	Departing Loads		Arriving Empties			
	to So. Water St		from So Water		Total	
TIME	Horse	Autos	Horse	Autos.	Loads	Empty
7 to 8	10	0	25	0	10	25
8 to 9	23	0	19	0	23	19
9 - 10	26	0	28	0	26	28
10 - 11	31	0	37	1	31	38
11 - 12	20	0	18	0	20	18
12 - 1	13	0	8	0	13	8
1 - 2	13	0	22	0	13	22
2 - 3	20	0	22	0	20	22
3 - 4	30	5	35	6	35	41
4 - 5	42	5	45	3	47	48
5 - 6	19	3	4	2	22	6
Total	247	13	263	12	260	275

260 Loads departing from M.C. CarLoad House.

5% were Auto Trucks

Figure 76

I.C. TRAFFIC COUNT. 32 A

Vehicles using River St and stopping at I.C house.

Station 7 located at north end of I.C In-bound house.

Counted by H.L.Blomquist Feb 20 1917

	Vehicles out & in using River St.				
	Loaded Out		Empty In		Total
	Horse	Auto	Horse	Auto	All.
8 to 9	25	4	25	6	60
9 - 10	23	6	21	4	54
10 - 11	23	2	14	2	41
11 - 12	22	3	17	5	47
12 - 1	1	0	5	0	6
1 - 2	18	1	28	3	50
2 - 3	21	2	28	4	55
3 - 4	16	2	24	3	45
4 - 5	26	9	22	2	59
Total	175	29	184	29	417

Total loaded vehicles outbound 204

Total empty vehicles inbound 213

Figure 77

I.C. TRAFFIC COUNT. 32 B

Traffic at I.C. In Freight House

Station 7 Using River St.

Counted by H.L.Blomquist Feb 21 1917

	Departing and going north to River St					
	LOADED		EMPTY		Total	Total
Time	Horse	Auto	Horse	Auto	Loads	Empty
7 to 8	5	3	15	5	8	20
8 to 9	14	5	17	0	19	17
9 - 10	13	7	20	13	20	33
10 - 11	20	10	30	3	30	33
11 - 12	15	5	16	2	20	18
12 - 1	5	0	5	0	5	5
1 - 2	14	2	14	6	16	20
2 - 3	15	4	28	5	19	33
3 - 4	33	10	43	7	43	50
4 - 5	18	3	19	9	21	28
5 - 6	21	0	17	0	21	17
Total	173	49	224	50	222	274

222 Loads departed via River St.

274 empties went north to River St.

19% were Auto Trucks

Figure 78

Illinois Central R.R. Traffic Count.

Station 8. Cor. South Water & Beaubien Ct. 33 A

East Bound Counted by F.L. Graybill
West Bound Counted by A.F. Angelmeyer Feb 20 1917

	VEHICLES GOING EAST			VEHICLES GOING WEST.				
	LOADED		Empty	LOADED		Empty	COAL	
Time	Horse	Auto	Both	Horse	Auto	Both	Horse	Auto
8 to 9	93	27	141	108	6	33	57	21
9 to 10	110	22	144	147	25	59	42	15
10-11	91	23	165	138	26	80	31	22
11-12	66	16	147	135	29	99	48	17
12-1	22	4	87	49	3	15	22	11
1-2	147	4	168	98	21	50	25	14
2-3	178	20	143	116	30	95	44	19
3-4	188	22	145	130	22	114	26	12
4-5	186	16	100	121	25	134	49	25
Total	1081	154	1240	1042	187	679	344	156

9 hrs

Total Vehicles Going East	2475
Total Vehicles Going West	1908
Total Coal Veh. Going West	500
Total Traffic East & West	4883

30% of all Coal Vehicles are Auto Trucks.
14% of all Commercial Veh are Auto Trucks.

Figure 79

Illinois Central R.R. Traffic Count.

Station 8 cor South Water & Beaubien Ct. 33 B

East bound counted by Graybill
West bound counted by Angelmeyer Feb 21 1917

	Vehicles Going East					Vehicles Going West					Coal	
	Loaded		Empty		Pass.	Pass	Loaded		Empty		Loaded	
Time	Horse	Auto	Horse	Auto	Autos	Autos	Horse	Auto	Horse	Auto	Horse	Auto
7 to 8	30	3	161	27	3	1	31	8	5	1	9	7
8 to 9	68	14	120	26	1	2	130	10	34	7	56	16
9-10	84	22	137	33	4	1	150	12	54	15	40	10
10-11	85	10	155	27	4	6	123	21	64	19	32	12
11-12	67	12	100	18	2	6	160	18	86	10	34	13
12-1	33	4	58	18	0	1	59	4	9	3	28	6
1-2	100	15	113	30	4	1	81	13	55	2	23	23
2-3	144	28	101	37	5	5	135	20	75	18	39	28
3-4	184	36	68	47	7	2	115	15	106	29	35	28
4-5	173	23	44	29	4	6	94	19	95	19	33	21
5-6	25	4	22	2	5	4	72	7	101	17	12	12
11 hrs	993	191	1079	294	39	33	1150	147	684	140	351	176

Total Vehicles going east	2596
Total Vehicles going west	2154
Coal Vehicles going west	527
Total east & west	5277

32% of all coal vehicles are Auto Trucks.
14% of all commercial veh. are Auto Trucks.

Figure 80

I.C. TRAFFIC COUNT. 34 A

Station 9 Consumers Coal Co.

Counted by R.J. Griffin Tuesday Feb 20 1917

Time	Coal Departing 1 horse	2 horse	3 horse	Autos	Empty returned	Total
8 to 9	0	2	2	9	12	25
9-10	1	1	2	9	22	35
10-11	2	4	1	8	12	27
11-12	0	1	1	9	9	20
12-1	0	1	1	0	9	11
1-2	1	3	1	6	6	17
2-3	2	4	1	7	10	24
3-4	0	3	1	9	10	23
4-5	1	4	2	5	9	21
Total	7	22	12	62	99	203

104 Loads of Coal departed

62 - or 60% were Auto Trucks

Figure 81

I.C. TRAFFIC COUNT. 34 B

at Consumers Co Coal Yard.

Station 9

Counted by R.J. Griffin Feb 21 1917

Time	COAL DEPARTING 2 horse	3 horse	Autos	Returned Empties	Total Departing
7 to 8	4	2	2	6	8
8-9	2	0	2	11	4
9-10	3	3	2	5	8
10-11	2	1	9	14	12
11-12	3	1	5	10	9
12-1	2	2	3	10	7
1-2	5	3	9	10	17
2-3	2	3	10	25	15
3-4	7	4	8	25	19
4-5	2	1	9	15	12
5-6	1	5	9	13	15
Total	33	25	68	144	126

Total loads departing 126

54% of the loads departed in Auto Trucks.

Figure 82

I.C. TRAFFIC COUNT.

Station 10 Henry Hafer Coal Co. (35 A)

Counted by F.L.Murray Tuesday Feb 20 1917

	Coal Departing				Empty return			
Time	1 H	2H	3H	Auto	1H	2H	3H	Total
8 to 9	1	7	5	1	3	2	1	20
9-10	2	2	0	0	3	2	3	12
10-11	2	5	4	1	3	3	1	19
11-12	3	4	2	0	1	2	3	15
12-1	0	2	2	0	1	3	3	11
1-2	2	5	3	0	0	3	3	16
2-3	1	0	0	1	1	3	1	7
3-4	2	4	2	0	1	4	1	14
4-5	0	3	0	0	0	3	0	6
Total	13	32	18	3	13	25	16	120

66 Loads of Coal departing

Figure 83

I.C. TRAFFIC COUNT. (35 B)

at Henry Hafer & Son Coal Yard

Station 10

Counted by F L.Murray Feb 21 1917

	COAL DEPARTING				Empties	Total
Time	1 horse	2 horse	3 horse	Autos	Returned	Departing
7 to 8	0	0	0	1	9	1
8-9	1	6	6	2	11	15
9-10	0	4	3	1	7	8
10-11	1	3	2	1	14	7
11-12	0	3	3	1	7	7
12-1	1	6	3	1	4	11
1-2	2	5	1	0	4	8
2-3	1	2	0	1	4	4
3-4	2	2	1	2	4	7
4-5	1	1	1	2	5	5
5-6	0	0	0	0	0	0
Total	9	32	21	11	72	93

93 Loads of Coal left the yard.

12% were Auto Trucks.

Figure 84

I.C. TRAFFIC COUNT. 36 A

Station 11 Crerar, Clinch & Co COAL.

Counted by R.C. Matlack Feb 20 1917

	Coal Departing				Empties	Total
Time	1 horse	2 horse	3 horse	Autos	returning	
8 to 9	7	34	21	11	25	98
9-10	3	14	13	10	35	75
10-11	3	7	5	8	31	54
11-12	5	27	12	12	31	87
12-1	0	6	11	8	25	50
1-2	2	14	9	12	28	65
2-3	3	10	8	12	35	68
3-4	2	15	11	12	35	75
4-5	3	21	11	12	21	68
Total	28	148	101	97	266	640

374 Vehicles Departed from the yard with coal.

97 or 27% were Auto Trucks

Figure 85

I.C. TRAFFIC COUNT. 36 B

Station 11 Crerar Clinch Co Coal.

Counted by R.C. Matlack Wed. Feb. 21 1917

	COAL DEPARTING				Empty	Total
Time	1 horse	2 horse	3 horse	Autos	return'g	Departing
7 to 8	0	1	1	3	50	5
8-9	3	22	20	12	12	57
9-10	3	17	14	10	14	44
10-11	1	7	10	18	39	36
11-12	1	18	8	13	19	40
12-1	1	11	3	6	8	21
1-2	2	4	5	15	51	26
2-3	2	11	4	20	35	37
3-4	2	14	6	16	38	38
4-5	0	18	6	11	31	35
5-6	0	2	1	1	1	4
Total	15	126	78	125	298	344

344 Loads departed.

36% were Auto Trucks.

37% " 3 horse Teams.

23% " 2 " "

4% " 1 " "

Figure 86

I.C. TRAFFIC COUNT. (37 A)

Station 12 at E.F. Daniels Coal Co.

Counted by D M Morgan — Tuesday Feb 20 1917

	Coal Departing			Empties	
Time	2horse	3horse	Autos	Returned	Total
8 to 9	2	3	2	9	16
9-10	3	2	0	1	6
10-11	1	2	1	2	6
11-12	2	3	1	12	18
12-1	3	4	0	0	7
1-2	0	7	3	0	10
2-3	2	1	3	0	6
3-4	2	2	1	0	5
4-5	2	2	1	0	5
Total	17	26	12	24	79

55 Loads departed

Figure 87

I.C. TRAFFIC COUNT. (37 B)

E.F. DANIELS COAL CO

Station 12.

Counted by D. Morgan — Feb 21 1917

	COAL DEPARTING			
Time	2horse	3horse	Auto	Total
7 to 8	0	1	3	4
8 to 9	3	2	3	8
9-10	2	1	2	5
10-11	3	3	1	7
11-12	3	2	1	6
12-1	0	1	0	1
1-2	1	2	3	6
2-3	1	3	1	5
3-4	2	2	3	7
4-5	1	4	3	8
5-6	0	0	2	2
Total	16	21	22	59

59 vehicles departed with coal

37% were Auto Trucks

Figure 88

I.C. TRAFFIC COUNT. 38 A

Station 13 at Warden Coal Washing Co.

Counted by R.J. Spickerman Feb 20 1917

	Coal Departing			Empties	Total
Time	2 horse	3 horse	Autos		
8 to 9	4	4	1	0	9
9-10	2	2	0	3	7
10-11	2	2	1	9	14
11-12	4	3	0	0	7
12-1	0	0	0	0	0
1-2	0	0	0	5	5
2-3	3	0	0	4	7
3-4	0	2	0	2	4
4-5	1	1	0	1	3
Total	16	14	2	24	56

32 Loads of Coal departed.

Figure 89

I.C. TRAFFIC COUNT. 38 B

Warden Coal Washing Co.

Station 13

Counted by R.J Spickerman Feb 21 1917.

	COAL DEPARTING				EMPTIES
	2horse	3horse	Autos	Total	Returning
7 to 8	0	0	0	0	8
8-9	3	3	1	7	1
9-10	1	0	1	2	0
10-11	0	0	0	0	5
11-12	3	1	0	4	4
12-1	0	3	0	3	1
1-2	1	0	0	1	1
2-3	0	1	1	2	4
3-4	2	1	0	3	2
4-5	1	0	0	1	1
5-6	0	0	0	0	0
Total	11	9	3	23	27

23 Loads departed from yard

13% were Autos.

Figure 90

I.C. TRAFFIC COUNT. 39 A

Station 16 F.G. Hartwell Co. Coal

Counted by L.R. Mellin Feb 20 1917

	Coal Departing				
Time	2horse	3horse	Autos	Total	
8 to 9	6	5	2	13	
9-10	0	0	2	2	
10-11	2	1	0	3	
11-12	5	3	1	9	
12-1	0	0	0	0	
1-2	3	1	0	4	
2-3	3	1	1	5	
3-4	4	1	2	7	
4-5	5	1	2	8	
Total	28	13	10	51	

Total Loads departing 51

20% were Auto Trucks.

Figure 91

I.C. TRAFFIC COUNT. 39 B

at F.G. Hartwell Co. Coal Yard.

Station 16

Counted by L.R. Millin Feb 21 1917

	COAL DEPARTING				
Time	2horse	3horse	Auto	Total	
7 to 8	4	0	2	6	
8-9	1	6	1	8	
9-10	0	0	1	1	
10-11	0	0	1	1	
11-12	5	4	1	10	
12-1	0	0	0	0	
1-2	2	0	3	5	
2-3	2	2	7	11	
3-4	4	0	4	8	
4-5	2	2	2	6	
5-6	1	2	3	6	
Total	21	16	25	62	

62 Vehicles departed with coal

40% were Auto Trucks.

Figure 92

I.C. TRAFFIC COUNT. (40 A)

Station 18 at the Morton Salt Co.

Counted by L.E.Walker Tuesday Feb 20 1917

	Salt Departing		Empties inbound		Total
Time	Horse	Autos	Horse	Autos	
8to9	4	2	7	2	15
9-10	6	1	4	2	13
10-11	2	2	6	0	10
11-12	6	1	5	0	12
12-1	0	1	4	1	6
1-2	4	0	2	1	7
2-3	4	1	6	1	11
3-4	4	1	1	0	6
4-5	0	1	3	1	5
Total	30	10	37	8	85

40 Loads departed

25% were Auto Trucks.

Figure 93

I.C. TRAFFIC COUNT (40 B)

Station 18 Morton Salt Co.

Counted by L.E.Walker Feb 21 1917.

	Salt Departing		Empties Returned		Total	
Time	Horse	Auto	Horse	Auto	Loads	Empty
7to8	5	3	0	0	8	0
8-9	2	0	2	0	2	2
9-10	2	2	1	3	4	4
10-11	4	2	4	1	6	5
11-12	3	1	3	2	4	5
12-1	1	1	3	1	2	4
1-2	3	1	3	0	4	3
2-3	5	0	3	2	5	5
3-4	3	2	3	0	5	3
4-5	1	0	1	0	1	1
5-6	0	0	6	2	0	8
Total	29	12	29	11	41	40

41 Loads departed

40 Empties returned.

30% Loads were Auto Trucks.

Figure 94

I.C. TRAFFIC COUNT.

Station 19 Western Cold Storage Co. (41 A)

Counted by Holland Roberts Feb 20. 1917

	Vehicles Inbound			Vehicles Outbound			
	Loaded		Empty	Loaded		Empty	
Time	Horse	Auto	Both	Horse	Auto	Both	Total
8 to 9	8	3	13	13	2	1	40
9 - 10	2	2	9	10	7	6	36
10 - 11	1	0	5	10	0	2	18
11 - 12	3	1	5	6	0	5	20
12 - 1	2	0	0	1	0	3	6
1 - 2	2	0	10	2	0	4	18
2 - 3	3	0	4	4	0	4	17
3 - 4	2	0	4	6	1	6	19
4 - 5	1	0	3	2	4	5	15
Total	26	6	53	54	14	36	189

Loads inbound 32
Loads outbound 68 Loads in & out 100
Empties inbound 53 Empties in & out 89
Empties outbound 36
Total 189

Figure 95

I.C. TRAFFIC COUNT.

at the Western Cold Storage Co. (41 B)

Station 19

Counted by H.D. Roberts Feb 21 1917

	Inbound Loads			Outbound Loads			Total	Total
Time	Horse	Autos	Empty	Horse	Autos	Empty	Loads in & out	Empties in & out.
7 to 8	0	1	21	0	1	0	2	21
8 - 9	2	1	15	20	4	2	27	17
9 - 10	0	2	5	12	0	0	14	5
10 - 11	1	1	9	3	1	1	6	10
11 - 12	1	0	11	8	2	2	11	13
12 - 1	1	0	1	6	0	1	7	2
1 - 2	2	0	15	1	0	3	3	18
2 - 3	3	2	7	10	2	4	17	11
3 - 4	2	2	6	4	1	4	9	10
4 - 5	3	4	8	6	3	1	16	9
5 - 6	1	1	1	8	3	2	13	3
Total	16	14	99	78	17	20	125	119

129 Inbound Vehicles

115 Outbound Vehicles

125 In & Out were loads

119 In & Out were empty.

Figure 96

I. C. R.R. Traffic Count. (42 A)

Station 20 Located at I.C. Outbound House

Counted by J. B. Lamar — Tuesday Feb 20 1917

	to I.C. Outhouse		from Team Trks		Total
	Loaded Inbound		Loaded Outbound		
Time	Horse	Autos	Horse	Autos	
8 to 9	60	5	40	2	107
9-10	43	13	41	6	102
10-11	40	4	49	9	102
11-12	45	10	62	11	128
12-1	15	1	4	1	21
1-2	68	11	46	9	134
2-3	70	16	56	11	153
3-4	84	8	56	13	161
4-5	87	6	78	5	176
9 hrs.	512	74	432	66	1084

Inbound to I.C. Freight House 586

Departing from Team Tracks 498

13% of all vehicles are Auto Trucks.

Figure 97

I. C. TRAFFIC COUNT. (42 B)

Traffic at I.C. outbound & I.C. Fruit Houses

Station 20 located at north-west cor. of Fruit Hse.

Counted by J. E. Lamar — Feb 21 1917

	Loads arriving at I.C. Out House		Loads departing from Fruit House		
Time	Horse	Auto	Horse	Auto	Total
7 to 8	30	3	10	2	45
8-9	40	10	8	3	61
9-10	66	10	48	13	137
10-11	50	7	52	7	116
11-12	47	4	71	5	127
12-1	23	1	9	0	33
1-2	58	8	36	4	106
2-3	82	8	67	15	172
3-4	121	12	75	15	223
4-5	83	11	94	9	197
5-6	8	0	87	8	103
Total	608	74	557	81	1320

682 Loads arriving at I.C. out freight house

638 Loads departing from I.C. Fruit House.

12% were Auto Trucks

Figure 98

I.C. TRAFFIC COUNT. (43 A)

at I.C.R.R. TEAM TRACKS

Station 21 located at south end of Dock House

Counted by R.C. Davies — Tuesday Feb 20 1917

	Arriving at Tracks				Departing from Tracks				
	Horse		Auto		Horse		Auto		
Time	Load	Empty	Load	Empty	Load	Empty	Load	Empty	Total
8 to 9	1	21	0	3	17	0	1	0	43
9-10	2	20	0	2	30	5	3	0	62
10-11	6	15	0	3	23	3	2	0	52
11-12	4	14	0	1	20	5	2	0	46
12-1	3	13	0	1	13	2	1	0	33
1-2	4	23	1	2	11	7	2	0	50
2-3	4	26	1	1	20	10	3	1	66
3-4	6	17	0	1	22	6	0	2	53
4-5	2	3	0	0	18	11	0	0	34
Total	32	152	2	14	174	48	14	3	439

Vehicles Arriving 200

Vehicles Departing 239

Figure 99

I.C. TRAFFIC COUNT. (43 B)

at I.C. Team Tracks

Station 21

Counted by R.C. Davies — Feb 21 1917

	ARRIVING				DEPARTING				
	AUTOS		TEAMS		TEAMS		Autos		
Time	Load	Empty	Load	Mty	Load	Mty	Load	Mty	Total
7 to 8	1	1	5	11	8	5	1	0	31
8-9	0	2	2	24	16	3	2	1	49
9-10	1	1	2	26	24	9	1	1	66
10-11	0	0	5	24	26	5	0	0	61
11-12	0	0	4	20	21	8	0	0	53
12-1	0	0	0	9	23	3	0	2	37
1-2	0	0	3	10	10	3	0	0	26
2-3	0	0	5	17	15	8	0	0	45
3-4	2	0	1	8	12	3	0	0	27
4-5	1	0	5	13	13	12	0	2	46
5-6	0	0	0	1	7	3	1	1	13
Total	5	4	32	164	175	62	5	7	454

37 vehicles arriving with loads

180 " departing " "

5% were Auto Trucks

Figure 100

I.C. TRAFFIC COUNT. (44 A)

Station 22 City Street Dirt.

Counted by A.H. Mc Gregor Feb 20 1917

Time	Cart Loads Arriving 3	Empties Departing
8 to 9	8	7
9 - 10	11	9
10 - 11	7	10
11 - 12	10	9
12 - 1	0	1
1 - 2	1	0
2 - 3	11	8
3 - 4	5	9
4 - 5	0	0
Total	53	53

Figure 101

I.C. TRAFFIC COUNT. (44 B)

Station 22 City Dump I.C Tracks.

Counted by A.H. Mac Gregor Feb 21 1917

Vehicles Arriving	
Time	Street Dirt
7 to 8	1
8 - 9	11
9 - 10	8
10 - 11	11
11 - 12	8
12 - 1	0
1 - 2	2
2 - 3	9
3 - 4	8
4 - 5	0
5 - 6	0
Total	58

58 Loads taken to I.C Tracks

Figure 102

I.C. TRAFFIC COUNT (45 A)

at I.C. Inbound Freight House

Station 23 located at south end of I.C. in frt hse

Counted by M.M.Kupferberg Tuesday Feb 20 1917.

	Vehicles Departing			Vehicles Arriving		
	LOADED		EMPTY	LOADED	EMPTY	Total
	Horse	Auto	Both	Both	Both	
8 to 9	15	2	7	1	23	48
9-10	19	3	11	6	33	72
10-11	21	3	7	8	30	69
11-12	26	9	7	8	25	75
12-1	4	1	1	2	5	13
1-2	28	8	12	4	35	87
2-3	23	5	14	11	25	78
3-4	33	4	6	11	21	75
4-5	33	6	8	14	15	76
Total	202	41	73	65	212	593

Vehicles departing from house 316

Vehicles arriving at house 277

total 593

Figure 103

I.C. TRAFF. COUNT. (45 B)

of L.C.L. traffic to and from I.C. in freight house

Station 23 at south end of I.C. in freight house

Counted by M.M.Kupferberg Feb. 21 1917

	Vehicles Departing			Arriving		
	Loaded		Empty	Loaded	Empty	Total
	Horse	Auto	Both	Both	Both	
7 to 8	6	3	4	1	30	44
8-9	20	1	6	9	21	57
9-10	36	9	12	13	28	98
10-11	32	9	10	12	28	91
11-12	29	5	13	10	28	85
12-1	4	0	3	4	2	13
1-2	27	3	10	8	29	77
2-3	39	8	13	18	17	95
3-4	27	6	7	11	21	72
4-5	32	14	12	11	24	93
5-6	14	4	6	4	3	31
Total	266	62	96	101	231	756

328 Loads departed from house.

20% were Auto Trucks

Figure 104

I.C. TRAFFIC COUNT

at M.C.R.R. TEAM TRACKS (46 A)

Station 24

Counted by J.S. Tyley Feb 20 1917 Tuesday.

	Vehicles Arriving			Vehicles Departing			
	LOADED		Empty	LOADED		Empty	Total
Time	Horse	Auto	Both	Horse	Auto	Both	
8 to 9	0	0	4	2	1	2	9
9-10	3	2	3	1	1	1	11
10-11	4	0	2	2	4	5	17
11-12	3	0	4	7	0	4	18
12-1	1	0	2	2	1	0	6
1-2	0	0	4	3	0	2	9
2-3	9	0	5	2	1	2	19
3-4	11	2	3	6	2	5	29
4-5	7	1	3	3	1	12	27
Total	38	5	30	28	11	33	145

Vehicles Arriving 73

Vehicles Departing 72

Figure 105

I.C. TRAFFIC COUNT. (46 B)

at the M.C. Team Tracks

Station 24

Counted by J.S. Tyley Feb 21 1917

	Arriving loaded			Departing loaded		
Time	Horse	Auto	Empty	Horse	Auto	Empty
7 to 8	0	0	7	4	0	0
8-9	0	1	9	5	1	0
9-10	4	0	5	8	0	0
10-11	2	0	8	7	0	1
11-12	4	0	9	11	2	3
12-1	0	1	6	2	0	0
1-2	2	0	3	1	2	0
2-3	5	0	4	2	0	0
3-4	4	0	9	1	0	2
4-5	3	0	6	6	1	0
5-6	2	0	0	2	2	1
Total	26	2	66	49	8	7

28 Loads brought to Team Tracks

57 Loads taken from Team Tracks.

Figure 106

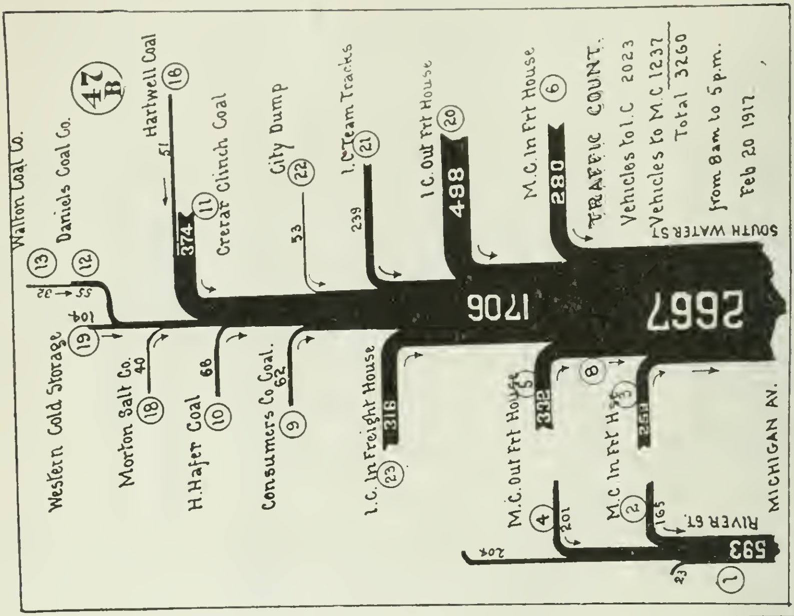


Figure 108

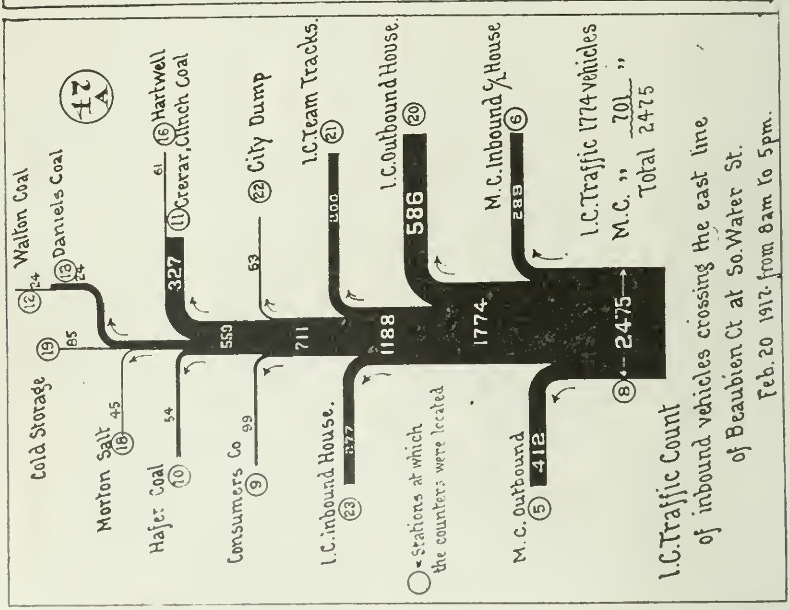


Figure 107

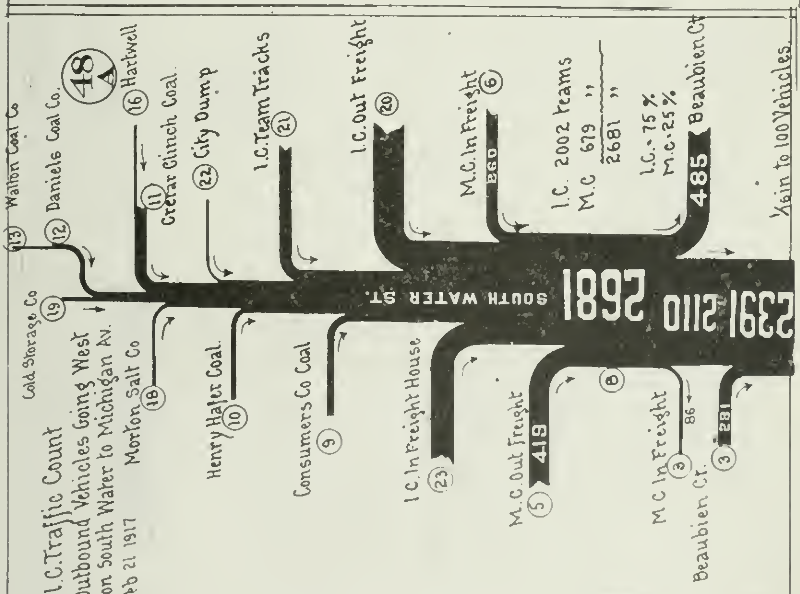


Figure 109

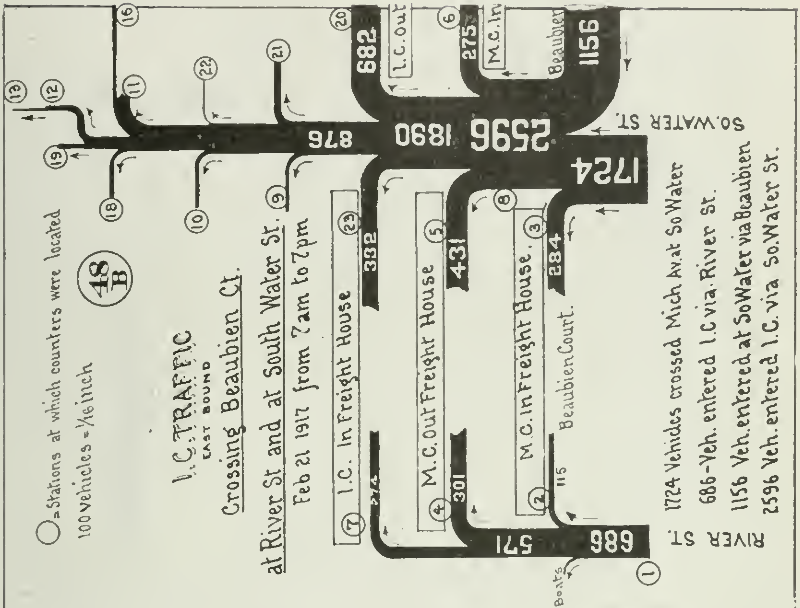


Figure 110

U.C. Traffic Count at S.W. Cor of So. Water & Beaubien Ct.
from 7 am to 6 pm on June 6th 1917
Taken by W. G. Crawford 1346 Madison Park.
50 A

	VEHICLES GOING EAST					GOING NORTH		GOING SOUTH		TOTAL
	LOADED		EMPTY			All Kinds		All Kinds		
TIME	Horse	Truck	Horse	Truck	Coal	Loads	Empty	Loads	Empty	-
7 to 8	13	3	98	10	6	9	6	2	1	148
8-9	20	8	68	10	9	1	8	4	3	131
9-10	40	13	62	3	11	4	8	4	1	146
10-11	33	14	57	11	7	6	10	1	2	141
11-12	33	8	38	3	6	5	8	2	8	111
12-1	12	2	8	4	1	3	2	0	1	33
1-2	57	17	47	4	6	3	7	3	0	144
2-3	77	21	42	7	1	7	7	4	5	171
3-4	90	37	22	4	4	10	4	5	1	177
4-5	91	17	13	2	6	2	1	0	5	137
5-6	11	4	4	0	1	3	3	0	0	26
Total	477	144	459	58	58	53	64	25	27	1365

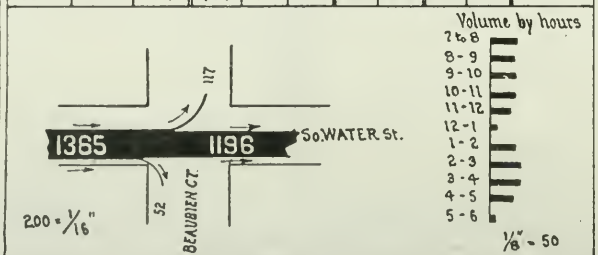


Figure 111

U.C. Traffic Count at S.W. Corner of So. Water & Beaubien
from 7 am to 6 pm on June 7th 1917
Taken by W. G. Crawford 1346 Madison Park
50 B

	VEHICLES GOING EAST					GOING NORTH		GOING SOUTH		Total
	LOADED		EMPTY			All Kinds		All Kinds		
Time	HORSE	TRUCK	HORSE	TRUCK	COAL	LOADS	EMPT	LOADS	EMPT	
7 to 8	22	3	73	6	12	1	5	3	3	128
8-9	15	10	70	9	8	4	8	5	1	130
9-10	40	11	69	8	7	7	6	8	1	157
10-11	48	9	68	10	11	2	8	3	1	160
11-12	38	10	39	10	7	1	12	5	1	123
12-1	11	6	21	6	1	1	0	0	0	46
1-2	55	10	39	11	6	4	4	4	1	134
2-3	79	13	39	8	9	7	9	4	3	171
3-4	85	39	28	10	7	11	6	2	0	188
4-5	87	18	27	3	2	12	4	2	1	156
5-6	16	2	5	0	0	0	0	0	0	23
Total	496	131	477	81	70	50	62	36	12	1415

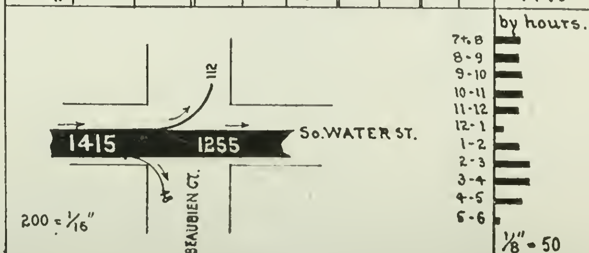


Figure 112

I. C. Traffic Count at N.E. Cor of So. Water & Beaubien Ct.
from 7 am to 6 pm on June 6th 1917
by H. K. Buchman 6217 Greenwood Av.
51 A

	Going West Loaded Horse	Going West Loaded Truck	Going West Loaded Coal	Going West Empty Horse	Going West Empty Truck	North All Kinds Loads	North All Kinds Empty	South All Kinds Loads	South All Kinds Empty	South Coal Loads	
7 to 8	100	6	5	11	0	1	2	3	2	4	134
8-9	131	7	12	33	6	2	4	28	9	24	256
9-10	129	17	11	48	5	7	11	33	10	12	283
10-11	114	21	7	33	5	6	16	28	13	9	251
11-12	101	11	11	33	8	10	10	25	13	13	235
12-1	47	6	5	12	3	1	0	7	3	14	98
1-2	56	14	12	24	4	6	3	13	13	12	157
2-3	88	13	6	53	11	6	8	27	7	10	229
3-4	82	23	9	71	8	6	5	33	13	15	265
4-5	65	12	10	58	15	12	12	10	6	10	210
5-6	34	8	2	50	6	5	8	14	12	2	141
Total	947	138	90	426	71	62	78	221	101	125	2259

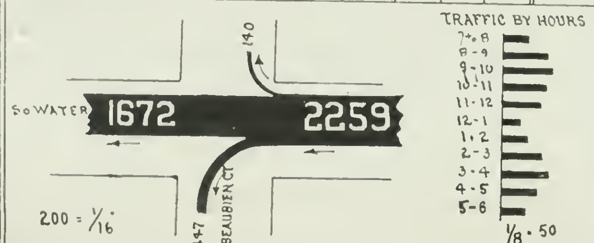


Figure 113

I. C. Traffic Count at N.E. Cor of So. Water & Beaubien Ct.
from 7 am to 6 pm on June 7th 1917
by H. K. Buchman 6217 Greenwood Av.
51 B

	Going West Loaded Horse	Going West Loaded Truck	Going West Loaded Coal	Going West Empty Horse	Going West Empty Truck	North All Kinds Loads	North All Kinds Empty	South All Kinds Loads	South All Kinds Empty	South Coal Loads	Total
7 to 8	82	7	8	11	0	0	0	7	1	5	121
8-9	145	8	9	18	5	7	9	39	3	19	262
9-10	117	15	10	19	4	9	4	30	8	15	231
10-11	110	17	8	42	4	10	10	24	3	7	235
11-12	104	21	12	39	7	10	4	33	12	11	253
12-1	26	10	1	11	0	1	2	12	1	9	73
1-2	55	14	6	25	9	8	3	16	6	4	146
2-3	86	20	10	46	4	5	8	24	16	9	227
3-4	77	26	14	55	13	8	4	39	16	8	260
4-5	90	25	6	80	10	12	15	30	19	6	292
5-6	61	15	5	64	2	9	9	21	14	6	207
Total	953	178	89	410	58	79	68	276	98	98	2307

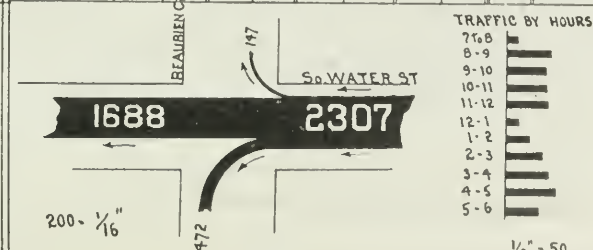


Figure 114

I.C. Traffic Count at S.E. Cor. of So. Water & Beaubien.

from 7 am to 6pm on June 6th 1917

by Wade S. Bender 5635 University Av.

52 A

	GOING WEST			NORTH		EAST.			Total
	All Kinds			All Kinds		All Kinds		COAL	
	LOADS	Empty	Autos	LOADS	Empty	LOADS	Empty	Empty	
7 to 8	0	1	0	0	6	29	29	3	68
8-9	5	0	0	2	7	26	45	2	87
9-10	1	2	2	0	9	40	44	1	99
10-11	0	0	0	0	5	36	43	12	96
11-12	0	2	1	2	3	33	22	4	67
12-1	0	0	0	2	2	8	13	9	34
1-2	5	1	1	2	4	35	22	10	80
2-3	2	3	5	5	7	55	32	13	122
3-4	3	0	1	8	9	65	16	3	105
4-5	2	0	3	8	5	58	10	3	89
5-6	3	3	5	0	0	8	3	1	23
Total	21	12	18	29	57	393	279	61	870

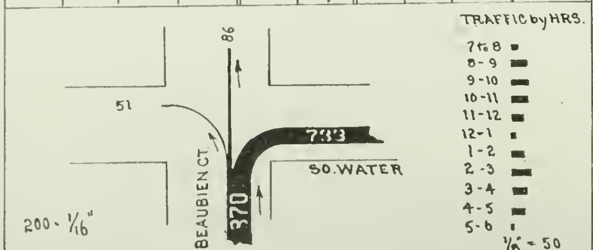


Figure 115

I.C. Traffic Count at S.E. Cor. of So. Water & Beaubien Ct.

from 7 am to 6pm on June 7th. 1917.

by Wade S. Bender 5635 University Av.

52 B

	GOING WEST			NORTH		EAST			Total
	All KINDS			All Kinds		All Kinds		COAL	
TIME	LOADED	Empty	Autos	Loaded	Empty	Loads	Empty	Empty	
7 to 8	1	0	0	1	3	12	45	3	65
8-9	0	0	1	1	4	31	44	6	87
9-10	4	0	2	4	8	29	51	5	103
10-11	0	2	0	3	6	42	32	8	93
11-12	0	0	1	2	3	37	25	10	78
12-1	0	1	0	0	1	14	15	5	36
1-2	4	1	4	1	6	47	19	9	91
2-3	1	0	2	3	6	69	33	5	119
3-4	2	0	1	2	6	78	22	4	115
4-5	1	2	0	2	4	84	18	2	113
5-6	1	0	10	1	0	6	6	4	28
Total	14	6	21	20	47	449	310	61	928

Figure 116

I.C. Traffic Count on N.W. Cor of Lake & Beaubien Ct.
from 7am to 6pm June 6th 1917.
by J.C. McKee 21 North Hall.

53 A

	GOING WEST						GOING SOUTH						
	LOADED				EMPTY		LOADED				EMPTY		Total
Time	Horse	Auto	Truck	COAL	Horse	Truck	Horse	Auto	Truck	COAL	Horse	Trucks	
7to8	4	1	0	3	2	1	1	0	0	0	2	0	14
8-9	30	6	2	20	8	0	5	1	0	0	2	4	78
9-10	38	6	1	14	11	2	6	0	4	1	4	2	89
10-11	23	3	1	9	14	1	10	0	1	1	8	2	73
11-12	25	3	2	7	16	1	6	1	0	0	10	5	76
12-1	5	3	0	10	5	0	2	1	1	2	2	0	31
1-2	18	3	3	19	11	3	6	0	2	1	3	1	70
2-3	25	8	3	8	6	5	6	2	2	2	7	0	74
3-4	29	4	3	8	17	0	7	2	2	1	3	1	77
4-5	17	6	2	12	11	1	3	2	3	4	4	4	69
5-6	11	9	0	2	12	2	1	1	0	0	9	3	50
Total	225	52	17	112	113	16	53	10	15	12	54	22	701

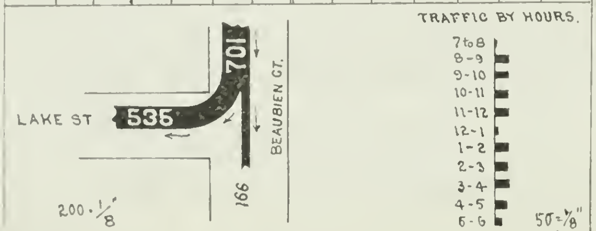


Figure 117

I.C. Traffic Count on N.W. Cor of Lake & Beaubien
from 7am. to 6pm. June 7 1917.
by J.C. McKee 21 North Hall

53 B

	GOING WEST.						GOING SOUTH						
	LOADED				EMPTY		LOADED				EMPTY		TOTAL
Time	Horse	Auto	Truck	COAL	Horse	Truck	Horse	Auto	Truck	COAL	Horse	Truck	
7to8	9	0	1	5	1	0	0	0	0	0	0	0	16
8-9	33	2	1	13	6	1	8	1	3	2	2	4	76
9-10	30	0	5	16	6	3	4	0	1	0	5	1	71
10-11	25	5	2	13	6	0	10	2	2	2	4	4	75
11-12	27	3	2	8	16	4	11	1	1	1	6	2	82
12-1	13	0	0	8	2	0	1	0	1	1	0	2	28
1-2	19	3	0	6	7	2	2	0	1	1	6	1	48
2-3	26	6	1	8	16	2	6	2	0	2	4	2	75
3-4	37	2	4	9	17	3	7	2	3	1	4	4	93
4-5	24	5	2	4	25	4	7	0	3	1	7	2	84
5-6	12	1	2	0	10	3	4	2	1	1	6	3	45
Total	255	27	20	90	112	22	60	10	16	12	44	25	693

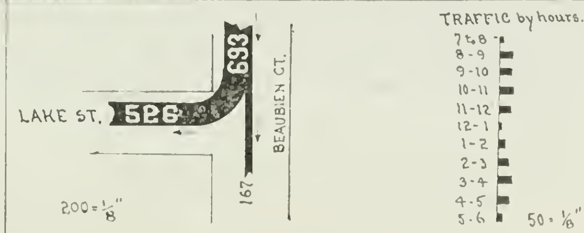


Figure 118

I. C. Traffic Count at S. W. Cor. of Lake & Beaubien Ct.
from 7am to 6pm on June 6th 1917
by J. L. Handelman 1200 W 12th St.
54 A

	ON BEAUBIEN GOING NORTH				ON LAKE GOING NORTH				GOING SOUTH		Total
	LOADED		EMPTY		LOADED		EMPTY		LOADS	Empty	by
Time	Horse	Truck	Horse	Truck	Horse	Truck	Horse	Truck	Horse	Truck	Hours
7 to 8	7	0	10	1	6	2	28	2	0	1	57
8-9	14	0	9	2	13	1	36	3	2	4	84
9-10	16	0	23	4	32	8	24	0	2	2	111
10-11	6	0	16	2	21	1	21	7	4	1	79
11-12	9	2	13	4	30	1	14	1	2	0	76
12-1	7	0	8	8	5	0	9	1	0	1	39
1-2	16	1	15	3	29	2	20	8	1	3	98
2-3	9	5	21	6	41	8	26	1	2	2	121
3-4	20	2	6	4	52	5	13	0	1	2	105
4-5	22	1	10	0	45	4	13	2	0	0	97
5-6	4	2	5	2	5	1	3	0	2	0	24
Total	130	13	136	36	279	33	207	25	16	16	891

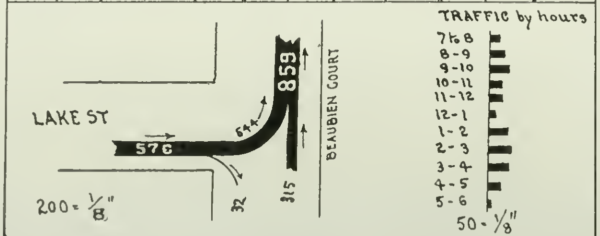


Figure 119

I. C. Traffic Count S. W. Cor. of Lake & Beabien Ct.
from 7am to 6pm on June 7th 1917
by J. L. Handelman 1200 W 12th
54 B

	ON BEAUBIEN GOING NORTH				ON LAKE GOING NORTH to B. CT				ON LAKE GOING SO		Total
	LOADED		EMPTY		LOADED		EMPTY		LOADED	EMPTY	by hours
Time	Horse	Truck	Horse	Truck	Horse	Truck	Horse	Trucks	Horse	Truck	Total
7 to 8	3	0	12	0	8	0	32	3	1	0	59
8-9	15	0	20	1	19	3	26	9	3	1	97
9-10	11	1	13	0	35	5	38	13	6	3	125
10-11	10	3	11	2	25	1	34	3	1	2	92
11-12	8	0	13	1	24	1	24	1	1	1	74
12-1	4	0	5	2	11	1	10	0	0	1	34
1-2	13	3	9	2	25	3	20	1	2	2	80
2-3	24	2	16	1	54	10	26	5	7	3	148
3-4	15	1	4	5	56	4	30	4	0	3	122
4-5	15	2	5	3	58	7	15	4	1	0	110
5-6	1	1	9	4	4	0	3	0	1	2	25
Total	119	13	117	21	319	35	258	43	23	18	966

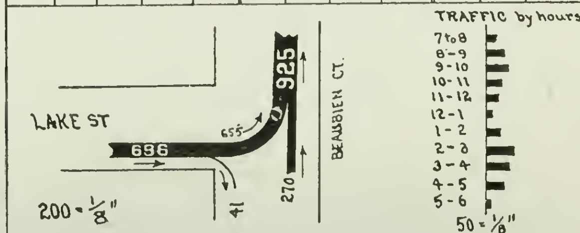


Figure 120

I.C. Traffic Count at Randolph & Michigan Av.
from 7am to 6pm on June 6 1917.
by Judson S. Tyley 6463 Kenwood Av.

55 A

	USING RANDOLPH ST VIADUCT							USING BEAUBIEN COURT.						
	GOING EAST			GOING WEST				GOING EAST			GOING WEST			Total
	All Kinds		COAL	All Kinds		COAL		All Kinds		COAL	All Kinds		Coal	
TIME	LOAD	MTY	MTY	LOAD	MTY	LOAD	MTY	LOAD	MTY	MTY	LOAD	MTY	LOAD	
7 to 8	1	4	28	3	0	1	2	7	15	1	2	1	0	65
8-9	5	4	6	2	0	3	1	13	9	0	10	6	0	59
9-10	3	4	6	1	6	5	0	23	18	3	10	12	1	102
10-11	5	4	10	2	7	4	0	17	11	6	16	11	1	94
11-12	3	2	7	0	2	3	0	20	10	4	12	10	0	63
12-1	2	1	5	0	2	3	0	8	9	7	0	3	1	41
1-2	1	4	5	1	2	2	1	13	5	3	6	4	0	47
2-3	1	2	6	1	2	2	0	18	13	6	13	11	2	77
3-4	4	1	3	1	3	3	0	17	7	3	4	7	4	57
4-5	3	1	1	4	3	3	0	18	7	0	7	7	1	55
5-6	2	0	0	0	1	2	0	5	4	0	5	6	0	25
Total	30	27	77	15	28	31	4	159	108	33	85	78	10	685

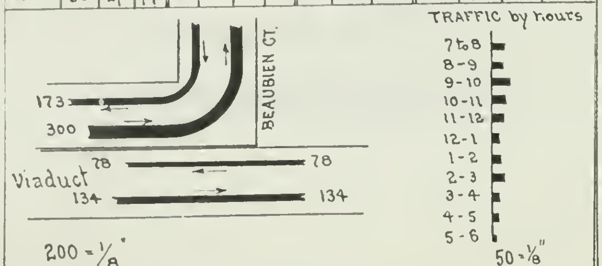


Figure 121

I.C. Traffic Count at Randolph & Michigan Av.
from 7am to 6pm on June 7 1917.
by Judson S. Tyley 6463 Kenwood Av.

55 B

	USING RANDOLPH ST VIADUCT							USING BEAUBIEN COURT						
	GOING EAST			GOING WEST				GOING EAST			GOING WEST.			Total
	All Kinds		COAL	All Kinds		COAL		All Kinds		COAL	All Kinds		COAL	
Time	LOAD	MTY	MTY	LOAD	MTY	Load	MTY	LOAD	MTY	MTY	LOAD	MTY	LOAD	
7 to 8	1	3	8	0	3	2	0	6	12	3	0	0	0	38
8-9	1	2	5	1	1	2	0	15	13	3	16	4	2	65
9-10	4	7	8	1	2	2	0	20	14	3	10	11	1	83
10-11	0	5	5	2	5	6	1	13	5	4	10	8	0	64
11-12	2	1	5	3	0	1	1	10	7	2	11	6	1	50
12-1	4	1	3	2	2	2	0	10	2	4	3	4	1	38
1-2	1	2	3	0	1	3	0	15	4	1	8	5	0	43
2-3	2	1	6	5	2	3	1	28	4	1	12	9	1	75
3-4	3	4	4	1	3	2	0	19	2	2	1	13	2	56
4-5	0	0	2	2	4	2	0	24	6	2	10	18	0	64
5-6	1	0	0	1	1	3	0	10	5	1	12	12	0	46
Total	19	26	49	18	24	28	3	70	73	26	93	85	8	622

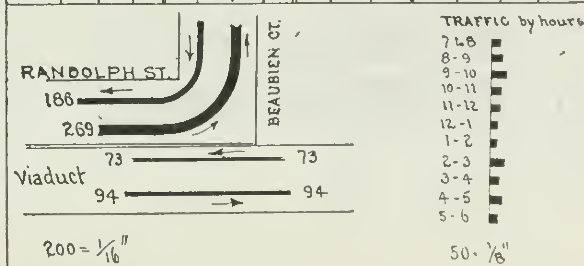


Figure 122

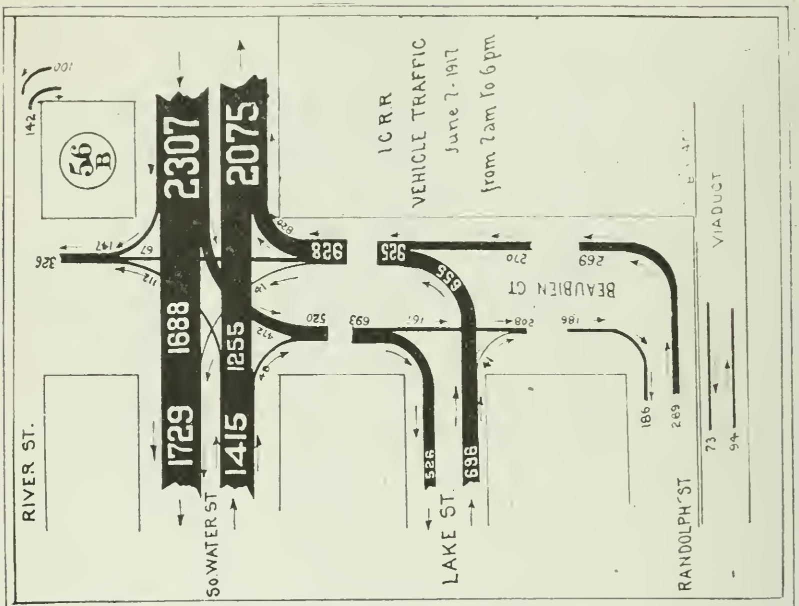


Figure 124

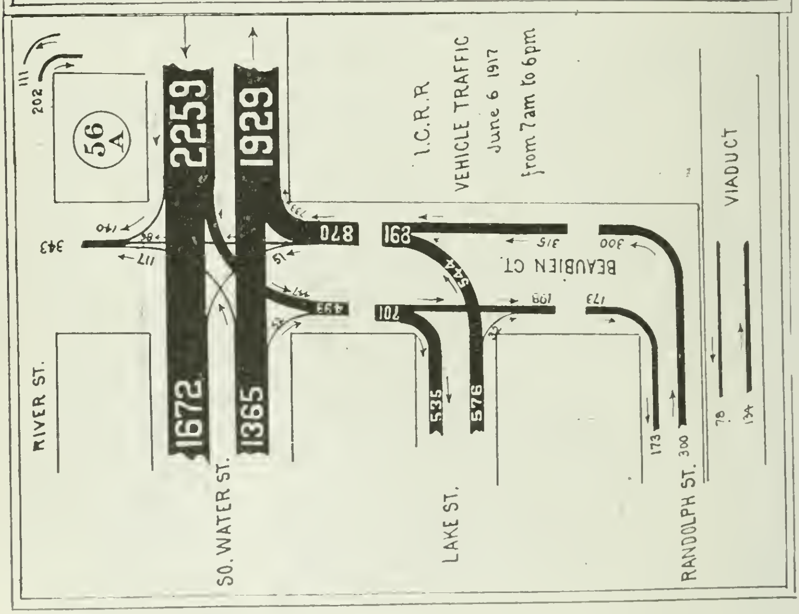


Figure 123

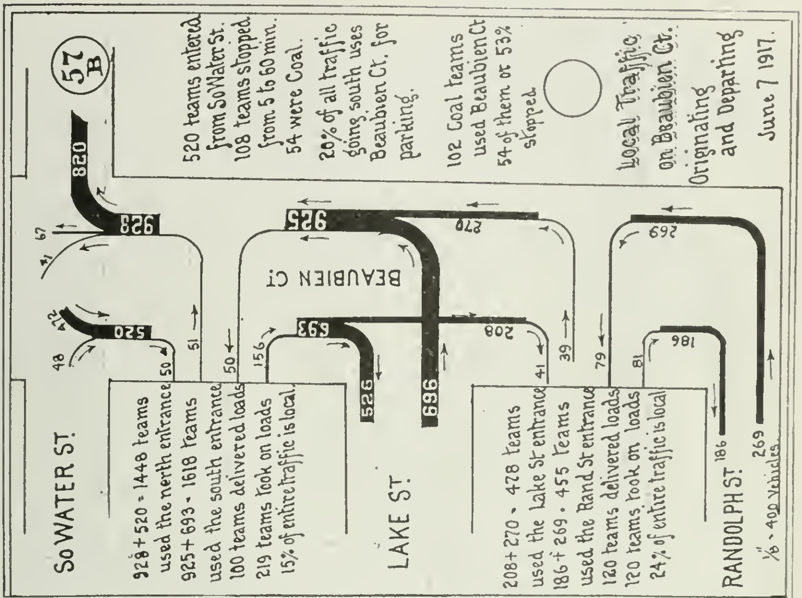


Figure 126

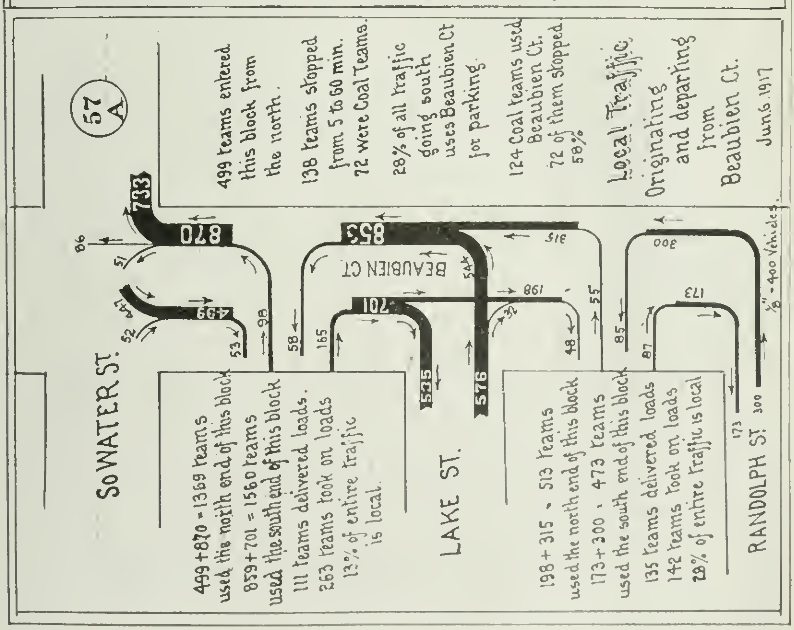


Figure 125

58 A

TRAFFIC INTERRUPTIONS at Michigan Av. & So Water St.

Observed by H.L. Blomquist & L.R. Mellin June 6 1917.

Time	Interruptions to Traffic each hour.	East & West TRAFFIC held up	North & South TRAFFIC held up	Time lost between signals	Length of Observation
8^{10} to 9	46	26 min.	19 min	5 min.	50 min
9-10	56	34 "	18 "	8 "	60 "
10-11	58	37 "	21 "	2 "	60 "
11-12	71	40 "	20 "	0 "	60 "
12-1	20	24 "	5 "	1 "	30 "
1-2	67	41 "	19 "	0 "	60 "
2-3	54	33 "	25 "	2 "	60 "
3-4	56	35 "	24 "	1 "	60 "
4-5	56	39 "	20 "	0 "	60 "
5-6	38	46 "	11 "	3 "	60 "
Total	522	365 "	183 "	22 "	9½ hrs
Average each hour.	55	38 "	20 "	2 "	

North & South Averages 550 Autos each hour going south.
East & West Averages 152 Teams each hour going west
1672 Teams going west are stopped on an up grade.

Figure 127

58 B

TRAFFIC INTERRUPTIONS at Michigan Av. & South Water

Observed by H.L. Blomquist & L.R. Mellin June 7 1917.

Time	Interruptions to Traffic each hour	East & West TRAFFIC held up	North & South TRAFFIC held up	Time lost between signals.	Length of Observation
8^{05} to 9	63	29 min.	20 min.	5 min	55 min
9-10	57	26 "	29 "	5 "	60 "
10-11	67	34 "	26 "	0 "	60 "
11-12	63	40 "	19 "	1 "	60 "
12-1	19.	25 "	4 "	1 "	30 "
1-2	56	44 "	16 "	0 "	60 "
2-3	57	36 "	24 "	0 "	60 "
3-4	60	34 "	25 "	1 "	60 "
4-5	61	37 "	23 "	0 "	60 "
5-6	47	40 "	14 "	1 "	55 "
Total	550	345 "	201 "	14 "	
Average each hour.	58	36 "	21 "	1' 30"	9½ hrs

North & South Averages 550 Autos each hour, going south.
East & West Averages 150 Teams each hour going west.
1688 teams going west are held up on an up grade.

Figure 128

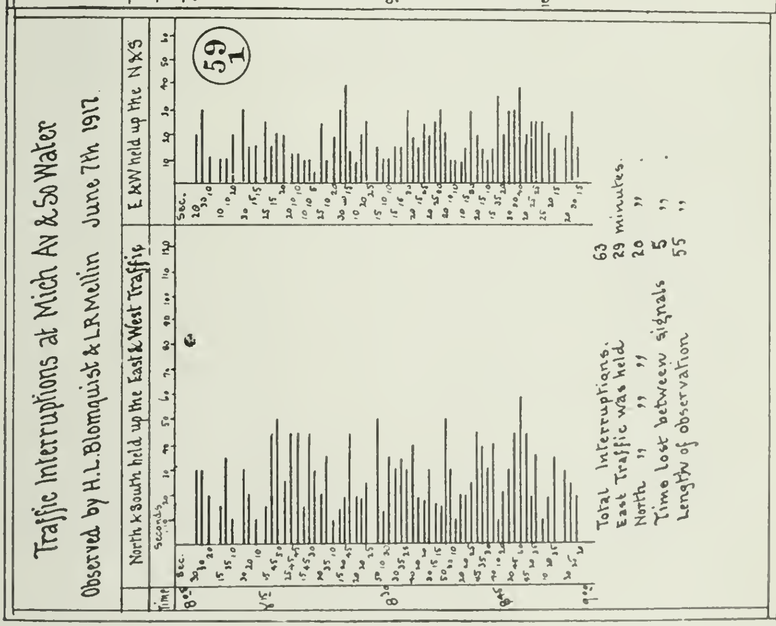


Figure 129

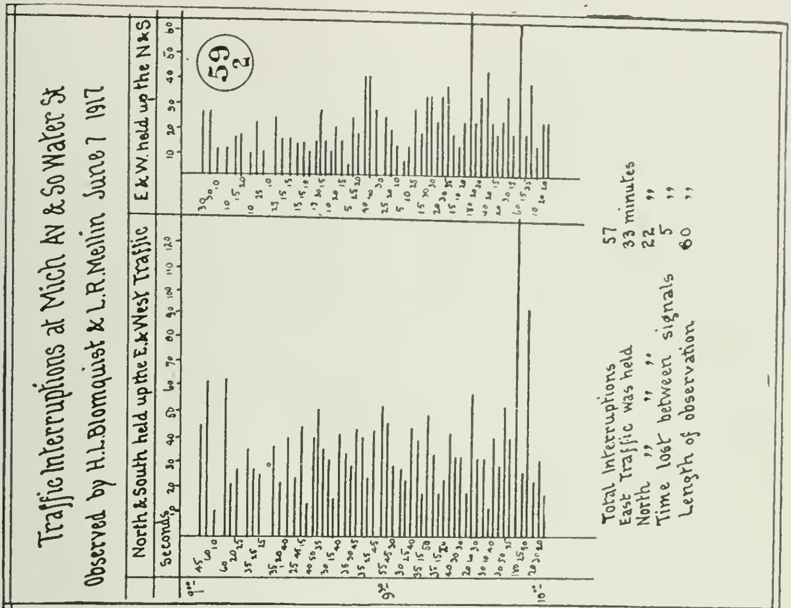


Figure 130

RECORD OF VEHICLE TRAFFIC ON WEST CHICAGO PARK COMMRS BOULEVARDS

1911 & 1914

WHERE TAKEN	1911			1914	SATURDAY SEPR 12TH 1914	SUNDAY SEPR 13TH 1914	WEDNESDAY SEPR 16TH 1914
WASHINGTON & HALSTED ST				AUTO	5831	3600	6188
				MOTOR	515	324	514
				HORSE	479	182	601
				TOTAL	6825	4106	7303
WASHINGTON & ASHLAND				AUTO	6472	4910	6820
				MOTOR	976	670	863
				HORSE	213	137	234
				TOTAL	7661	5717	7917
WASHINGTON & SACRAMENTO				AUTO	6402	5993	7018
				MOTOR	1037	789	806
				HORSE	121	81	170
				TOTAL	7560	6663	7994
WASHINGTON & N. LARAMIE (52ND AVE)				AUTO	5534	9349	5840
				MOTOR	620	996	741
				HORSE	106	90	80
				TOTAL	6360	10435	6661
WASHINGTON & (44TH AVE) N KOSTNER	MONDAY - SEPR 18TH 1911	AUTO	5373				
		MOTOR	1095				
		HORSE	683				
		TOTAL	7151				
JACKSON BLVD & HALSTED ST	SUNDAY - SEPR 10TH 1911	AUTO	4893	AUTO	5300	4118	6153
		MOTOR	843	MOTOR	589	744	1232
		HORSE	759	HORSE	410	261	801
		TOTAL	6495	TOTAL	6299	5123	8186
JACKSON & ASHLAND	SUNDAY - SEPR 17TH 1911	AUTO	3127	AUTO	5394	4456	5087
		MOTOR	847	MOTOR	992	935	790
		HORSE	405	HORSE	179	121	209
		TOTAL	4379	TOTAL	6565	5512	6086
JACKSON & OAKLEY	THURSDAY - SEPR 14TH 1911	AUTO	871				
		MOTOR	529				
		HORSE	333				
		TOTAL	1733				
JACKSON & SACRAMENTO	MONDAY - SEPR 11TH 1911	AUTO	765	AUTO	3298	4056	3551
		MOTOR	406	MOTOR	700	870	812
		HORSE	260	HORSE	79	57	97
		TOTAL	1431	TOTAL	4077	4983	4460
DOUGLAS BLVD & INDEPENDENCE SQ	TUESDAY - SEPR 19TH 1911	AUTO	790				
		MOTOR	354				
		HORSE	185				
		TOTAL	1329				
W 12TH ST BOULD & S ROBEY ST.	FRIDAY - SEPR 15TH 1911	AUTO	655				
		MOTOR	256				
		HORSE	273				
		TOTAL	1184				
LOGAN BOULD & N WESTERN AV	SATURDAY - SEPR 16TH 1911	AUTO	548				
		MOTOR	270				
		HORSE	131				
		TOTAL	949				
HUMBOLDT BLVD & PALMER SQR	TUESDAY - SEPR 12TH 1911	AUTO	880				
		MOTOR	342				
		HORSE	214				
		TOTAL	1436				

Figure 131

RECORD OF VEHICLE TRAFFIC ON WEST CHICAGO PARK COMM^RS BOULEVARDS.
SEPTEMBER 12TH 1914.
SATURDAY

WHERE TAKEN		7 AM TO 8 AM	8 AM TO 9 AM	9 AM TO 10 AM	10 AM TO 11 AM	11 AM TO 12 AM	12 TO 1 PM	1 PM TO 2 PM	2 PM TO 3 PM	3 PM TO 4 PM	4 PM TO 5 PM	5 PM TO 6 PM	6 PM TO 7 PM	7 PM TO 8 PM	8 PM TO 9 PM	9 PM TO 10 PM	10 PM TO 11 PM	11 PM TO 12 PM	12 TO 1 AM	1 AM TO 2 AM	2 AM TO 3 AM	3 AM TO 4 AM	4 AM TO 5 AM	5 AM TO 6 AM	6 AM TO 7 AM	TOTAL	GRAND TOTAL	REMARK
WASHINGTON & HALSTED	AUTO	190	325	398	480	420	465	340	500	330	385	305	585	190	180	180	105	150	100	105	45	17	7	6	23	5831		
	MOTOR	50	29	35	24	27	64	40	55	23	32	64	20	—	7	17	6	4	6	1	3	1	—	1	6	515	6825	
	HORSE	24	47	58	56	34	47	26	23	45	24	20	16	6	5	6	4	4	7	3	8	4	4	1	7	479		
	TOTAL																											
WASHINGTON & ASHLAND	AUTO	243	385	410	455	405	438	420	386	600	457	431	304	257	289	302	205	187	95	92	35	26	16	8	26	6472		
	MOTOR	45	47	66	47	67	93	75	60	81	58	62	27	38	51	44	21	13	8	7	9	1	—	3	3	976	7661	
	HORSE	11	20	23	24	15	19	10	13	16	12	13	10	4	9	2	4	1	2	2	1	2	—	—	—	213		
	TOTAL																											
WASHINGTON & SACRAMENTO	AUTO	255	365	325	331	330	325	390	436	430	462	567	360	375	375	280	256	206	102	118	45	19	10	14	26	6402		
	MOTOR	78	28	46	36	57	82	62	71	121	67	91	42	91	40	39	22	25	5	5	9	1	—	5	14	1037	7560	
	HORSE	10	7	6	10	3	11	10	13	9	16	8	10	4	—	—	1	1	—	—	1	—	—	—	1	121		
	TOTAL																											
WASHINGTON & N. LARAMIE (52ND AVE)	AUTO	230	285	253	190	259	260	328	380	505	515	535	350	405	320	265	240	167	90	78	31	21	12	10	35	5534		
	MOTOR	44	21	19	19	35	53	35	40	79	49	58	32	26	26	16	21	17	11	4	3	1	—	3	8	620	6360	
	HORSE	1	3	6	5	5	3	7	9	25	9	9	6	3	2	—	1	—	—	1	1	—	2	1	2	106		
	TOTAL																											
JACKSON & HALSTED	AUTO	235	410	445	315	325	355	330	480	379	319	376	197	188	230	182	135	138	82	72	31	21	17	5	33	5300		
	MOTOR	44	66	85	30	25	45	23	45	44	33	33	23	23	17	12	5	14	8	5	—	—	4	3	5	589	6299	
	HORSE	49	45	25	43	15	27	25	38	35	21	20	21	5	2	—	2	2	4	2	6	1	4	4	14	410		
	TOTAL																											
JACKSON & ASHLAND	AUTO	167	298	313	299	343	332	358	380	420	410	465	275	260	275	255	125	147	80	80	41	25	20	12	14	5394		
	MOTOR	68	35	55	41	66	87	90	75	80	55	82	41	71	60	23	18	12	11	8	5	—	1	3	5	992	6565	
	HORSE	10	24	13	12	15	10	12	9	20	6	7	11	3	2	2	2	1	—	—	—	4	3	4	9	179		
	TOTAL																											
JACKSON & SACRAMENTO	AUTO	135	240	190	165	175	190	260	290	280	290	360	225	205	245	190	120	150	63	66	21	16	7	26	19	3298		
	MOTOR	41	20	25	45	25	35	57	67	66	70	89	32	34	34	17	8	11	6	5	5	2	1	2	3	700	4077	
	HORSE	6	7	3	6	3	5	5	9	9	4	1	1	3	1	3	1	4	—	—	1	2	1	3	1	79		
	TOTAL																											

Figure 132

RECORD OF VEHICLE TRAFFIC ON WEST CHICAGO PARK COMM^RS BOULEVARDS
SEPTEMBER 13TH 1914
SUNDAY

WHERE TAKEN		7 AM TO 8 AM	8 AM TO 9 AM	9 AM TO 10 AM	10 AM TO 11 AM	11 AM TO 12 AM	12 TO 1 PM	1 PM TO 2 PM	2 PM TO 3 PM	3 PM TO 4 PM	4 PM TO 5 PM	5 PM TO 6 PM	6 PM TO 7 PM	7 PM TO 8 PM	8 PM TO 9 PM	9 PM TO 10 PM	10 PM TO 11 PM	11 PM TO 12 PM	12 TO 1 AM	1 AM TO 2 AM	2 AM TO 3 AM	3 AM TO 4 AM	4 AM TO 5 AM	5 AM TO 6 AM	6 AM TO 7 AM	TOTAL	GRAND TOTAL	REMARK
WASHINGTON	AUTO	47	80	127	180	191	230	160	179	205	320	355	255	280	230	170	185	155	80	44	25	15	7	20	60	3600		
&	MOTOR	10	10	8	18	17	21	23	33	62	25	20	20	8	10	10	6	2	2	–	1	1	1	3	13	324	4106	
HALSTED.	HORSE	10	11	15	13	7	9	6	4	5	10	2	2	3	5	5	–	4	2	1	4	8	8	17	31	182		
	TOTAL																											
WASHINGTON	AUTO	37	82	155	248	255	303	242	297	289	403	480	379	385	407	321	223	181	52	43	29	16	9	18	56	4910		
&	MOTOR	14	29	31	45	48	49	52	66	60	45	63	31	30	42	16	12	8	3	2	5	2	–	3	14	670	5717	
ASHLAND	HORSE	2	8	13	10	11	10	10	12	11	7	10	4	7	8	1	2	–	–	–	2	4	–	–	5	137		
	TOTAL																											
WASHINGTON	AUTO	45	102	170	270	343	364	296	407	418	547	669	522	345	402	356	258	214	72	41	17	12	9	22	92	5993		
&	MOTOR	10	23	34	67	69	67	57	80	75	59	59	43	22	35	13	12	10	5	4	3	1	3	3	35	789	6663	
SACRAMENTO	HORSE	7	11	3	1	5	3	3	10	8	4	11	5	3	2	2	–	–	–	–	–	–	–	–	3	81		
	TOTAL																											
WASHINGTON	AUTO	50	104	251	375	455	477	452	900	1076	1000	1200	810	560	515	405	282	173	60	21	14	4	2	12	70	9349		
&	MOTOR	15	24	67	70	94	76	75	75	91	97	116	58	36	23	26	16	13	8	3	1	–	–	2	10	996	10435	
N. LARAMIE	HORSE	1	2	1	3	2	4	4	8	9	8	30	2	2	3	1	1	–	–	2	–	–	2	3	2	90		
(52ND AVE)	TOTAL																											
JACKSON	AUTO	51	113	77	180	395	280	275	190	344	378	361	278	260	239	179	177	106	65	68	17	10	2	13	60	4118		
&	MOTOR	20	23	105	70	25	25	105	107	38	60	40	26	13	20	9	10	10	4	2	–	–	1	2	29	744	5123	
HALSTED	HORSE	10	7	10	10	20	22	51	32	10	10	2	5	3	5	4	1	3	1	–	4	6	9	5	31	261		
	TOTAL																											
JACKSON	AUTO	46	82	142	206	264	264	214	291	460	415	400	343	300	285	235	170	130	70	60	22	10	5	10	32	4456		
&	MOTOR	23	58	49	76	72	111	98	76	63	60	60	40	42	28	20	8	14	7	4	3	–	–	2	21	935	5512	
ASHLAND	HORSE	6	3	6	8	11	8	6	11	8	8	3	4	3	6	3	1	1	–	–	2	4	3	8	8	121		
	TOTAL																											
JACKSON	AUTO	20	45	175	215	290	230	200	365	415	350	345	275	245	265	183	155	125	65	26	13	7	4	12	31	4056		
&	MOTOR	15	50	50	60	86	95	70	57	73	79	67	50	25	18	21	9	8	7	–	1	–	3	4	22	870	4983	
SACRAMENTO	HORSE	1	–	3	8	5	4	7	6	3	3	2	4	2	3	–	–	1	–	–	–	–	–	1	4	57		
	TOTAL																											

Figure 133

RECORD OF VEHICLE TRAFFIC ON WEST CHICAGO PARK COMM^RS BOULEVARDS
SEPTEMBER 16TH 1914.
WEDNESDAY.

WHERE TAKEN		7 A.M. TO 8 A.M.	8 A.M. TO 9 A.M.	9 A.M. TO 10 A.M.	10 A.M. TO 11 A.M.	11 A.M. TO 12 A.M.	12 TO 1 P.M.	1 P.M. TO 2 P.M.	2 P.M. TO 3 P.M.	3 P.M. TO 4 P.M.	4 P.M. TO 5 P.M.	5 A.M. TO 6 P.M.	6 P.M. TO 7 P.M.	7 P.M. TO 8 P.M.	8 P.M. TO 9 P.M.	9 P.M. TO 10 P.M.	10 P.M. TO 11 P.M.	11 P.M. TO 12 P.M.	12 TO 1 A.M.	1 A.M. TO 2 A.M.	2 A.M. TO 3 A.M.	3 A.M. TO 4 A.M.	4 A.M. TO 5 A.M.	5 A.M. TO 6 A.M.	6 A.M. TO 7 A.M.	TOTAL	GRAND TOTAL	REMARK
WASHINGTON & HALSTED	AUTO	196	355	450	450	410	368	423	425	340	535	600	305	190	275	205	210	190	80	73	15	8	19	16	50	6188		
	MOTOR	57	31	30	27	25	30	30	29	19	45	88	23	20	10	10	8	6	2	4	2	1	—	1	16	514	7303	
	HORSE	54	60	61	48	30	45	40	30	29	40	32	15	8	2	8	3	4	4	2	12	9	10	16	39	601		
	TOTAL																											
WASHINGTON & ASHLAND	AUTO	225	435	397	410	364	430	393	404	406	433	742	427	322	473	380	266	146	48	31	17	12	8	14	37	6820		
	MOTOR	88	77	38	35	28	50	32	30	39	81	139	49	33	59	35	22	11	5	3	1	2	—	1	5	863	7917	
	HORSE	14	33	13	17	19	15	13	11	23	11	24	12	4	11	5	2	—	1	1	1	2	—	—	2	234		
	TOTAL																											
WASHINGTON & SACRAMENTO	AUTO	270	419	354	375	280	280	318	345	440	357	795	590	415	462	455	362	196	98	57	11	6	4	21	108	7018		
	MOTOR	77	48	32	35	20	30	47	42	51	33	97	46	35	75	31	16	14	11	9	2	—	1	2	52	806	7994	
	HORSE	10	13	17	11	9	6	13	13	19	12	21	1	7	7	4	—	1	—	—	—	—	—	—	6	170		
	TOTAL																											
WASHINGTON & N LARAMIE (52nd AVE)	AUTO	183	380	253	238	188	263	225	250	320	445	520	485	375	545	400	345	215	70	32	8	2	3	10	85	5840		
	MOTOR	37	30	28	52	39	43	24	37	45	53	58	48	42	56	55	25	30	18	4	—	—	—	2	15	741	6661	
	HORSE	2	5	2	2	4	6	2	6	10	15	15	—	2	1	—	—	—	—	1	—	2	3	1	1	80		
	TOTAL																											
JACKSON & HALSTED.	AUTO	160	375	230	425	475	535	560	610	612	414	455	216	153	290	225	155	119	61	45	25	8	2	8	45	6153		
	MOTOR	61	90	15	122	100	80	192	128	134	26	83	31	40	30	25	13	15	9	3	2	2	—	2	29	1232	8186	
	HORSE	60	60	45	120	35	60	125	140	25	23	30	17	6	1	4	—	4	2	—	7	2	4	7	24	801		
	TOTAL																											
JACKSON & ASHLAND	AUTO	152	292	286	299	260	265	319	262	369	340	545	253	260	351	265	243	125	73	56	26	7	4	10	25	5087		
	MOTOR	75	43	40	23	27	34	43	45	48	36	89	36	66	60	20	36	20	12	6	3	1	2	5	20	790	6086	
	HORSE	12	24	23	16	6	17	13	13	29	7	10	8	4	2	2	2	1	1	—	1	5	3	7	3	209		
	TOTAL																											
JACKSON & SACRAMENTO.	AUTO	150	205	195	180	180	195	240	215	190	175	210	240	215	280	240	134	73	52	36	12	4	3	9	18	3551		
	MOTOR	55	75	50	30	25	50	35	48	90	67	71	31	58	27	39	13	10	5	7	2	—	6	1	17	812	4460	
	HORSE	2	4	10	3	6	5	10	6	9	9	13	2	4	5	3	2	1	—	—	—	—	—	1	2	97		
	TOTAL																											

Figure 134

BOOK REVIEWS

Stresses in Structural Steel Angles, With Special Tables. By L. A. Waterbury. 77 pages 5¼ by 8. Illustrated. Bound in cloth. Published by John Wiley & Sons, Inc., New York. Price, $1.25 net.

It has required many years of careful design to bring the present structural steel shapes to their present form. For many years each mill rolled its own shapes, and designing was, to a large degree, a matter of which mill the steel would be purchased from. Fortunately this has been well standardized now, but there are still many points to be cleared up with regard to the behavior of steel shapes under special conditions. Steel angles are used extensively in construction, and their lack of symmetry of section introduces conditions which the average designer is too apt to leave to the factor of safety. For those who wish to investigate the subject in its entirety the author has prepared a number of tables of value in considering various practical problems. These include Elements of Angles with Equal Legs, Elements of Angles with Unequal Legs, Coordinates of Section Modulus Polygons for Angles, Efficiency and Allowable Tension for Angles Riveted Through One Leg to a Rigid Connection Plate with Two Lines of Rivets and Efficiency and Allowable Tension for Angles Riveted Through One Leg to a Rigid Connection Plate with One Line of Rivets.

Among the subjects discussed in detail are, Relation Between Bending Moment and Flexural Stress, Expressions for the Section Modulus, Product of Inertia, Section Modulus Polygons, Neutral Axis, Plane of Loading, Combined Stresses, Flexure for Angles in Pairs, Transfer of Stress by Shear to an Outstanding Leg, and Efficiency of End Connections.

It will be seen that both the tables and the subjects discussed are of value to the designing engineer, as well as to the theorist or the student. The direct manner in which each subject is taken up and treated permits the author to include in a small book what could easily have been expanded to many more pages without in any way detracting from its value.

C. A. M.

An Elementary Outline of Mechanical Processes. By G. W. Danforth, U. S. Navy. 427 pages 6 by 9 inches, with many illustrations. Bound in cloth. Published by the United States Naval Institute, Annapolis, Maryland.

Mechanical processes have become exceedingly complex in many lines during the past few decades. Electricity has had much to do with this, while advances in chemistry has added its part to the perfection of materials and methods of manufacture. As it would be manifestly impossible to include everything on the subject in detail, the author has restrained his desire to cover the subject fully by condensing a vast amount of information in the given number of pages. By far the greatest part of the volume is devoted to the metals, and practically every process used in the practical arts is described in sufficient detail to enable the student to discuss it intelligently when the occasion arises. Primarily arranged for the instruction of midshipmen at the U. S. Naval Academy, it will be of great interest to students of technical schools everywhere who wish to obtain an excellent idea of the materials used in engineering construction, the essential features of the methods of producing them, shop processes and equipment for shaping the metals into the various forms in which it is used in engineering and construction, particularly mechanical and marine engineering construction.

Comparatively little time is spent on theoretical work, as it is the apparent aim of the author to give the reader a working knowledge of the essential facts connected with each subject. It is sufficient to know how iron ore

is brought through to rolled shapes, and that automatic screw machines will perform several operations on a bit of metal with little attention from the operator. It requires only a little more detailed study of the machine to realize both its possibilities and limitations. Besides, the student interested in these subjects is going to spend many hours around shops perfecting his knowledge in detail, so why burden the schoolroom with a study of what can be seen in a few minutes in the actual shop?

In general, the chapters are divided into Engineering Materials, General Outline of Metal-Producing Processes, Fuels, Iron and Steel, Mechanical Treatment of Metals, Heat Treatment, Re-Manufacture of Metals, Shops of Machinery Building and Repairing Plants, Pattern Shop, Foundry, Blacksmith Shop, Machine Shop, Boiler Shop, Other Shops, Special Processes, and an Appendix containing various tables of especial reference to the text.

C. A. M.

Oxy-Acetylene Welding Practice. By Robert J. Kehl, M. E. 102 pages 5½ by 8½, with many illustrations. Bound in cloth. Published by the American Technical Society, Chicago. Price, $1.00.

While high temperature flames, such as the oxy-hydrogen flame, were known for many years, the discovery of cheap methods of making acetylene and oxygen is comparatively recent, and it is due to these discoveries that the great advance in methods of using the oxy-acetylene flame for various purposes has been possible.

Mechanical processes in other lines seemed to demand this system, and in such work as automobiles and aeroplanes the full value is realized.

This book has been prepared with the idea of making workmen more familiar with the technical principles of using the flame and with the most effective methods for various purposes. The manager and superintendent also are interested in the book, as it will enable them to devise simpler methods for various operations about their plants.

Besides descriptions of the apparatus used, there are detailed instructions for performing various operations, for working with different metals, and on different classes of work. While automobile repair is given especial mention, it will be seen that similar methods are adaptable to other lines of work.

C. A. M.

Applied Mechanics. By Alfred P. Poorman. First edition. 244 pages, with numerous drawings and illustrations. Bound in cloth. Published by McGraw-Hill Company, Inc., New York. Price $2.00.

In preparing a text-book for engineering schools it is customary to consider that the student is already well versed in the general principles of Physics, Calculus, etc. To do otherwise would be to burden the book with a mass of elementary mathematics of no use to the student.

In preparing this book the Author starts boldly on the subject of Applied Mechanics and carries the student through the problems with very little in the nature of a General Introduction.

Among the subjects treated in detail we find Statics, Concurrent Forces, Parallel Forces, Non-Concurrent Forces, Non-Parallel Forces, Centroids and Center of Gravity, Friction, Moment of Inertia, Kinetics, Rectilinear Motion, Rotation, Combined Translations and Rotation, Work and Energy, Impulse and Momentum and Impact.

Each subject is divided into numerous problems covering the various phases of the subject and particular attention might be called to the extended use as being made of the Graphic method of Solution. This is valuable not only in the ease and rapidity with which it may be applied to the solution of certain classes of problems and on account of the aid which it gives in understanding the Algebraic method as well as a valuable check

upon the other. The two principles are in each problem developed practically together so as to show their inter-relation.

Another special feature is in the number of illustrations and examples which has been solved in detail in order to show the relation between the principles developed and the particular problems to which they apply.

This book will be of particular interest in Engineering Schools and Colleges, in connection with structural design and other engineering courses.

C. A. M.

PROCEEDINGS OF THE SOCIETY MINUTES OF THE MEETINGS

Meeting No. 993, Monday, February 5' 1918.

This was a general meeting of the Society for February, and was called to order at 8 p. m., by First Vice-President Jas. N. Hatch. There were present 72 members and guests. The Chairman introduced the speaker of the evening, Prof. John F. Hayford, M.W.S.E., Dean of the College of Engineering, Northwestern University, and member of the National Advisory Council for Aeronautics. The subject of Prof. Hayford's address was, "What American Science Is Doing for Aviation." The address covered the history of aviation, including the experiments made by Mr. Octave Chanute and described in his paper, "Gliding Experiments," presented before the Western Society of Engineers in 1897; also the continued improvements of the aeroplane and its adoption as a war machine. The address was discussed by Messrs. Grant, Lowell, Dalstrom, Lenth, Ball and Williams.

Meeting No. 994, Tuesday, February 12, 1918.

This was a meeting of the Bridge and Structural Section. It was called to order at 8 P. M. by John W. Lowell, Jr., Chairman of the Section. Present, 175 members and guests of the Society. The subject of the evening was "Progress in the Application of Concrete to Barge and Ship Building." This was presented by Mr. J. E. Freeman, Assoc. W.S.E., Technical Engineer, Portland Cement Association of Chicago. The speaker gave a comprehensive review of the progress of the use of concrete in the construction of ships, and illustrated the same with numerous slides, showing the details of construction. A moving picture illustrating the launching and the trial trip of a concrete ship in Norway was shown. The paper was discussed by Messrs. DeBerard, Hatch, Dalstrom, Lourie, Donavan, Goldberg, O'Sullivan, Forsyth, Goetz, Jennings, Dilling, Parker and Gerber.

The Secretary announced that the following had been elected to membership of the grades indicated:

Carl O. Soderquist, Chicago	Affiliated Member
Harold S. Bradley, Canada	Associate Member
Max L. Loewenberg, Chicago (transfer from Junior)	Associate Member
John Ahnfelt, Chicago	Affiliated Member
Abraham Mechin, Chicago	Student Member
Robt. A. Gates, Chicago	Student Member
Paul B. Waldron, Pittsburgh	Associate Member
Pete J. Herold, California	Associate Member
Jas. R. Allen, Chicago	Associate Member
Edw. C. Holden, Chicago (transfer from Junior)	Associate Member
Geo. H. Brown, Middletown, O	Associate Member

Meeting No. 993, Monday, February 5th, 1918.

The meeting was called to order at 8 p. m., by Mr. J. N. Hatch, Vice-President. This meeting was the regular Washington Evening of the Society. Mr. A. S. Baldwin, M.W.S.E., Chief Engineer, I. C. Ry., read a paper prepared by Mr. Jas. P. Nelson, Valuation Engineer of the C. & O. Ry. System, describing the James River and Kanawha Canal. This canal was one of the waterway projects of George Washington. Mr. Baldwin, before presenting the paper of Mr. Nelson, described the engineering activities of George Washington in connection with the Inland Waterway Systems proposed in the later part of the Eighteenth Century.

Lantern slides showing the planning of the District of Columbia as a site for the capital of the United States, and the notable construction features of the City of Washington, including the present extension of the park systems in the District of Columbia was presented by Edgar S. Nethercut.

The meeting was also the regular business meeting of the Mechanical

Engineering Section. Mr. C. O. Norwood, member of the Executive Committee, presiding. The following officers were elected for the Section:

Chairman..J. L. Hecht
Vice-Chairman.................................... Frank Rasmussen
Directors........................C. O. Bellow and P. Albert Poppenhusen

The proposed rules of the Section, having been previously read before the Section, were considered and adopted, subject to the approval of the Board of Directors. The meeting was attended by 40 members and guests.

Meeting No. 996, Monday, February 25, 1918.

This was a joint meeting of the Electrical Engineering Section and the Chicago Section, A.I.E.E. The meeting was called to order by C. A. Keller, Sec'y Chicago Branch, A.I.E.E. A three-reel motion picture was presented, entitled, "The Benefactor." This picture followed the career of Mr. Thos. A. Edison from his early life, and showed particularly his arduous labors in the invention of the incandescent lamp.

The speakers of the evening were introduced by C. W. Pendel. Mr. Thaddeus Bailey, President Elec. Furnace Co., presented a paper on "Resistance Type Furnaces of Large Capacity for Temperature of From 400° to 1200° C." It was illustrated by lantern slides. Mr. John A. Seeds of the General Elec. Company, presented a paper on "Arc Type Electric Furnaces of Sizes Varying from Those Designed for Laboratory Use Up to the Very Largest." This paper was illustrated by lantern slides. The subjects were discussed by Mr. C. F. Busse, of the Hoskins Mfg. Co., with illustrations of the Resistance Type Furnaces. Further discussion was had by Mr. H. M. St. John, Douglas Walker, A. Herz, J. Gardner and G. A. Hart. There were present 221 members and guests.

EDGAR S. NETHERCUT,
Secretary.

Journal of the Western Society of Engineers

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SNOW REMOVAL

By Harry Richards.*

Presented March 4, 1918.

Up to the time of the advent of the automobile in sufficient numbers to demand respectable attention, the South Park Commissioners did not follow a policy of cleaning snow off drives in the parks and on the boulevards; in fact, the snow was purposely left on the drives to provide sleighing for the public. Some twelve years ago, however,—about 1906,—the Park Commissioners started the practice of plowing the snow off drives to provide safer travel for the greatly increasing number of autoists. The equipment used for this purpose at that time was horse-drawn road grading machines.

When a fall of snow was four inches or less, we sent out ten plows,—five left-hand plows and five right-hand plows,—on a fifty-foot driveway, the idea being to bring all of the snow from the center of a drive to the gutters. When a snowfall was more than four inches and less than eight inches we started one of the plows drawn by four horses near the gutter to throw the first cut of snow on to the planting space or edge of the sidewalk, then followed with four other plows working from the center to the gutter.

Later the plan of plowing the snow from the gutters to the center of a drive was adopted, but there were several reasons why we abandoned this method of snow cleaning;—one reason being that because of the automobiles, milk wagons and other vehicles standing along the curbs it was impossible to get the snow cleaned along the gutters; another reason was that when the ridge of snow in the center of the street began melting the water ran towards the gutters, sometimes freezing before reaching them and thereby coating the drive surfaces with ice, which made it quite dangerous for traveling; a third reason being that it was ever so much harder work for the teams, inasmuch as they were plowing uphill from gutter to the crown of the drive.

*Superintendent of Maintenance and Repairs, South Park Commissioners.

The most unusual weather conditions with the abnormal snowstorms of the present winter have brought forcibly to our attention the inadequacy of the ordinary snow-handling equipment in such times of great need, and the pressing necessity for further development of machines and methods that can be depended upon to respond promptly and efficiently to any calls that may be made upon them in the line or snow removal service.

All will without doubt readily agree that the amount of snowfall during the January storms was most extraordinary,—the records of the Weather Bureau giving the total snowfall for the month as 42.5 inches, the greatest for any one month in Chicago in the history of the Bureau, which was established about 1873. Another feature quite unusual about this great snowfall was that storm followed storm in fairly rapid succession after the first heavy blizzard of January, making it quite impossible, with the means at our disposal, to get things opened up in the intervals between them. And then as the storms were accompanied by high winds the snow was blown about, ground up very finely and drifted into banks that were at some places six or more feet deep.

The South Park Commissioners did the best they possibly could with the men and equipment at their command, but did not succeed in making much headway against the overwhelming odds. Under such unlooked for conditions it will hardly evoke much wonder that it only too soon became painfully evident that all the snow cleaning equipment on hand proved entirely inadequate to make any considerable and reasonably rapid progress in opening the badly blocked walks and drives to the traveling public, which was never so sorely in need of open thoroughfares as at that very time.

In this connection I will mention the fact that it was very clearly demonstrated to me how necessary it is to have the boulevards in first class condition after a big storm. During the heavy January storms the auto traffic coming north on Michigan Avenue turned west on reaching Twelfth Street to Wabash Avenue and then following the Wabash Avenue car tracks north to the loop. I heard from quite a number of autoists that it required an hour or longer in most cases to travel on Wabash Avenue from 12th Street to Madison Street on account of the congestion of the traffic. The Street Car Company deserves a great deal of credit for their efforts to open and keep opened the various car lines which furnished a means for the traveling public to get around on their business where outside streets were practically impassable.

PLOWS MEET WATERLOO

All of the special motor snow plows of the South Park Commissioners, those equipped with V-shaped plows, from which we could usually expect fairly rapid and efficient service in ordinary snowfalls, met their Waterloo in the January storms, became stalled

in the drifts and were compelled to give up the battle. Straight moldboard plow attachments on motor trucks proved no better. This left us with slowly drawn plows of the road grader type as our only means (aside from hand shovel work) of opening passageways through the tightly packed and badly drifted snow. The areas covered by the Park Commissioners in their snow cleaning work include about 67 miles of drive, 175 miles of walk and from 90 to 95 acres of skating ice. Of course the main arteries of travel are cleaned first and the work is then extended as fast as possible to the balance of these surfaces.

Wherever it was possible for horses to travel the grader plows followed and cut openings through the snow. There were places where for a block or more the snow was quite deep on the level and where drifts three to five feet deep were encountered by the horse plows, but by persistent efforts we managed,—with considerable difficulty in some cases it is true,—in navigating the plows through such places. It was a frequent occurrence to be obliged to dig the horses themselves out of the drifts in which they became stalled. Progress could only be made by using four horses on a grader and at first we found fourteen such grader outfits necessary to open a passage way through the drifts along the boulevard wide enough after one trip along it to permit an automobile to make its way through. These fourteen plows were so set that the blades cut through the snow at a sharp angle, each plow opening as narrow a cut as possible, and even then seven graders were sent ahead to break a way through and scrape some snow off the top, which the seven following behind opened down to the pavement. Later when more headway had been made these narrow passageways through drifts were widened by hand shoveling to allow two machines to pass each other.

I need not tell you in detail how wearing such work proved on the park's heavy draft horses,—how the horses came in at the end of a day's work with their heads hanging low, all wet with perspiration and apparently over-fatigued, nor how slowly the work seemed to progress with teams unable to go faster than a walk through the deep snows. All the snowplows the Park Commissioners possessed, —37 large drive cleaning plows, 6 small walk cleaning plows, in addition to the skating ice cleaning equipment, such as Ajax scrapers, were pressed into service, the neighborhood for miles around being scoured for hired teams for operating them. Yet in spite of all our efforts in this line the progress seemed discouragingly slow. From the first some laborers were at work with shovels in the downtown district and permission was afterwards secured to supplement the horseplows in the larger parks and on the other boulevards with laborers also. For a while around five hundred laborers were busy with large shovels widening the passageways through the drives and opening walks throughout the South Park system. Business houses along some of the boulevards offered at times the services of their

employes to assist in snow removal work, which offers were accepted, the Park Commissioner furnishing the shovels. The cleaning of the skating ice was necessarily postponed until the thoroughfares of travel were made passable.

Those persons familiar with snow removal work need not be told of the several kinds of snow and the peculiarities involved in handling each of them,—the dry feathery snow, the ground up sand-like snow such as that of our big January snows, the heavy, wet, soggy snow, etc. The ground up snow which packs and piles up like sand dunes is especially difficult to move. When snow plows operate in light feathery snow the snow alongside of the plows, not being very compact, will give way to make room for the windrows delivered from the plow blades. The ground up sandy snow,—the January kind,—being already thoroughly compacted, will not and can not shove over to make room for any from the ordinary plow blade, unless there is an extraordinary power reserve behind it. In such a snow with ordinary equipment the snow moved to open a passageway must be lifted bodily and piled on top of that on either side. This was one factor which severely handicapped the snow removal work and hindered rapid progress in January. It is without doubt the most difficult snow cleaning season the South Park Commissioners have had to deal with since the advent of the automobile. It is to be hoped that the experience gained by municipalities in different parts of the country where heavy snowfalls have occurred will result in perfecting methods and machines for cleaning snow that will prove more capable, efficient, rapid and reliable than any that have been resorted to in the past. As it is now, after the past winter's work, the only reliable means of driveway cleaning the South Park Commissioners have found practical (aside from hand shoveling) proved to be the identical one we began this kind of work with twelve years ago.

No doubt city officials in charge of snow cleaning or street cleaning work have given great thought to the removal of snow, but no one I know of has gone into the methods of handling the snow in a manner radically different from that in which it has been handled for the past ten or twelve years. All the intervening seasons have not succeeded in producing a more reliable or efficient method of handling snows of this kind (the sandy kind), or developed even one implement or machine that could operate at all in it or plow continuously through it. I am of the opinion that auto plows with straight moldboards of the proper design will prove quite efficient in a fall of snow that is not too heavy, say from two to twelve inches, provided the machines can get traction and have plenty of power. My experience leads me to believe that the snow removal equipment for use in the South Park system should consist of straight moldboard plows, V-shaped plows, rotary plows, a loading machine and large specially designed wagons or auto trucks of

large capacity, the latter for hauling snow away from the downtown streets and certain intersections to some convenient place to dump where they can enter without becoming stuck.

Snow removal work in general presents problems quite difficult to handle and I feel safe in saying that persons who have had no actual experience in that line of work hardly realize the factors that cause the trouble and the difficulties that must be overcome before satisfactory solutions of these problems can be developed. While no doubt a machine can be designed whose operation will be elastic enough to handle the different kinds of snow encountered in a season satisfactorily, in the speaker's opinion a great deal of experimentation will be necessary under actual working conditions to evolve snow handling equipment that will prove reasonably satisfactory for the varying requirements of this line of work. Such undertakings must be thoroughly and scientifically gone into and worked out and will necessarily demand the expenditure of considerable money, probably more than any one particular concern would be willing to defray. It is hoped that some co-operative plan can be brought about whereby different large cities and municipalities interested in this work can be induced to pool their interests and appropriate proportionally to a fund to be used in arriving at a practical solution of the perplexing problems of snow removal work in cities. In some such way the burden of cost can be distributed so as not to become too oppressive to any one concerned and experts can be secured to devote sufficient time and ability to the work to master its problems and produce results that will be heartily welcomed by those in charge of snow cleaning work in our cities and by the public in general.

As to unit costs for snow cleaning work, some figures giving the cost per mile, per 1,000 square yards of pavement and per cubic yard of snow moved are shown in the attached statement. These costs are based on a rate of 75 cents per hour,—$6.00 per eight-hour day,—for a team and driver. They do not provide for finished cleaning over the various driveways of the South Park system, but cover primarily the clearing away of the "roughage" after snowstorms, such as can be accomplished by a single trip of the battery of plows over the different drives. Where two teams are used on a grader plow, the second driver operates the plow adjustments, so no laborers are necessary in such cases. As will be seen, the cost per mile for cleaning outside of the downtown district ranges from $8.31 per mile as the minimum for a four-inch snowfall to $14.98 per mile as the maximum cost for a six-inch snow, two teams being used on each grader.

In some instances but one team is used on a grader and then a laborer is required to man the plow. It has been found that this reduces the cost of a single trip cleaning of a certain driveway, making it from $5.40 per mile for a snow of four or five inches to $7.20 per mile for a fall of from five inches to a foot, when the team

hire is $6.00 per eight-hour day and the rate for labor is 30 cents per hour.

Carefully kept records show that the work of cleaning snow off drives with tractors after ordinary snowfalls can be done at a cost somewhat less than with horse-drawn machines and with them the work progresses much more rapidly too. In breaking up packed snow and ice the tractor outfits have proved themselves particularly adapted, while they are able to pile the snow over the curbing better than horse-plows, leaving the gutters open.

The South Park snow handling equipment at the present time includes five three-wheeled tractors fitted with detachable V-shaped plows having wing extensions and with detachable revolving street brooms, one four-wheeled tractor equipped with both V-shaped and straight moldboard attachments, some very large snow hauling wagons, twenty large four-wheeled iron plows of the road grader type, seventeen large wooden four-wheeled plows similar to the road graders, six small iron wheeled plows used mainly for cleaning snow off sidewalks around the smaller parks, several straight moldboard attachments for auto trucks, and then a considerable number of large Ajax scrapers, triangle plows, ice shaving machines, etc., used in cleaning the fields of skating ice.

About three winters ago a snow slushing machine was constructed for the purpose of disposing of snow in the downtown district through the sewers instead of loading it on wagons and trucks and hauling it to a dump. This was a small machine, consisting of a water turbine with a supply line to a fire-plug, so patterned that it would hang in a sewer manhole in a wire mesh basket, three free blades connected with the turbine chopping the snow and with the aid of the water from the turbine exhaust forcing or washing it through the wire basket into the sewer where the current of water and sewage took it away. The basket served to keep pieces of wood, bricks and other rubbish from passing along into the sewer and possibly clogging it.

In January of this year the abnormal snowfall plainly showed the necessity of a powerful and efficient machine to handle snow rapidly and in large quantities. After a little experimental work a two-disk rotary snowplow was constructed and given some preliminary tests, but the lateness of the season did not permit perfecting it. With more power, however, it gives promise of being developed into a practical affair.

MEMORANDUM ON COST OF CLEANING SNOW OFF DRIVES WITH HORSE-DRAWN PLOWS

Cost of cleaning the driveway from the Washington Park stables south along east side of Washington Park to Midway, then across south drive of Midway and south on west drive in Jackson Park and across past main golf shelter to 67th Street and Yates Avenue, and south over South Shore Drive to 83rd Street,—a total

distance of five miles,—ranging in width from 32 feet south of 71st Street, 36 feet on Yates Avenue to 40 feet on the balance of the way.

For a Snowfall not Exceeding 4 or 5 inches

1 grader plow with four horses, 4 hours at 75c per hour per team	$6.00
5 grader plows, each with two horses at 75c per hour per team (4 hours each)	15.00
5 laborers to operate plows, each 4 hours at 30c per hour	6.00
Total cost to clean 5 miles	$27.00
Average cost *per mile*	5.40

For a Snowfall of From 4 or 5 inches to a Foot or More

6 grader plows, each with four horses, each working 4 hours at 75c per hour per team	$36.00
Cost to clean a *mile*	$ 7.20

SOUTH PARK COMMISSIONERS' OUTLINE OF A PLAN FOR CLEANING SNOW FROM DRIVEWAYS

Time Required—Three Days

First Day. A. M.) Plowing snow to the gutters from Washington Park stables to 12th Street and Michigan Avenue, over the following driveways:

	Width-Ft.	Area-Sq. Yds.	Miles.	Cubic Yards of Snow on Drive.	
Washington Park (part)	40—50	30,000	1.20		
Grand Blvd. (center drive)	55	64,416	2.00		
So. Park Ave. (35th to 33rd)	42	6,122	0.25		
33rd Street (So. Pk. to Mich.)	42	8,282	0.31	at 4 in.	at 6 in.
Mich. Ave. (33rd to 12th)	50	67,320	2.25		
Total		176,140	6.01	19,571	29,357

For a 4-inch snowfall it is estimated that 40 horses (5 right 4-horse hitches and 5 left 4-horse hitches) will be required to plow these drives in five hours before noon. At the rate of $6.00 per 8-hour day for team and driver, the cost will be $75.00.

For a 6-inch snowfall it is estimated that 48 horses (6 right 4-horse hitches and 6 left 4-horse hitches) will be required. At the rate of $6.00 per 8-hour day for team and driver, the cost for 5 hours' work will be $90.00.

COST OF PLOWING SNOW OFF ABOVE DRIVEWAYS

	Per mile of drive.	Per 1,000 sq. yds. pavement.	Per cu. yd. of snow.	Total cost (without overhd)
For 4 inch snowfall	$12.49	$.427	$.00384	$75.00
For 6 inch snowfall	14.98	.512	.00307	90.00

First Day. (P. M.) In the afternoon half of the teams which plow from the park stables to 12th Street and Michigan Avenue in the morning will plow snow to the sides of the drives on:

	Width, feet.	Area, sq. yds.	Length, miles.	Cubic yards of snow on drive. at 4 in.	at 6 in.
Drexel Blvd. (both drives)....	40	70,224	3.00		
Oakwood Blvd................	50	17,060	0.50		
Wash'ton Pk. (part of drives).	40—50	20,000	0.80		
The other half of the teams will plow:					
Garfield Blvd. (So. Pk. to State)	40	11,733	0.50		
Michigan Ave. (55th to 33rd)..	50	82,228	2.75		
Total		201,245	7.55	22,360	33,541

The cost of the afternoon's work (5 hours) will be the same as for the morning's plowing,—$75.00 for a 4-inch snowfall and $90.00 for a 6-inch snowfall. These drives will not be gone over twice, but it is intended to go over the drives between the Washington Park stables and 12th Street on Michigan Avenue twice in order to get them as clean as possible, as the first trip over the drives usually does not remove all of the snow.

COST OF PLOWING SNOW OFF DRIVES CLEANED IN THE AFTERNOON OF THE FIRST DAY

	Per mile of drive.	Per 1,000 sq. yds. of pavement.	Per cu. yds. of snow.	Total cost (without overhd.)
For 4 inch snowfall.....	$ 9.94	$.373	$.00336	$75.00
For 6 inch snowfall......	11.93	.448	.00268	90.00

Second Day. (*Nine Hours' Work*)—Half of the teams will plow to the gutters on:

	Width, feet.	Area sq. yds.	Length. miles.	Cubic yards of snow on drive. at 4 in.	at 6 in.
Garfield Blvd. (South drive—State to Western)..........	40—25	56,691	3.00		
Garfield Blvd. (North drive—South Park to Western)....	40—25	68,424	3.50		
Other half of the teams will plow snow on:					
A. M. (From park stables to 79th Street and Bond Avenue.)					
Washington Park (part of drives)	40—50	10,000	0.40		
Midway (south drive)........	40	21,910	1.00		
Jackson Park (part of drives)...	40	44,000	2.00		
Yates Ave. (71st St. and Bond Ave. to 79th.)..............	32—38	36,500	1.75		
P. M. In the afternoon over the following drives:					
Fifty-first St. (inc. Drexel Sq.)	40	31,976	0.94		
East End Avenue.............	50	18,700	0.65		
Jackson Park (rest of drives in "outer" circle)..............	40	70,000	3.00		
Total		358,201	16.24	39,800	59,700

As this is a 9-hour day, the cost of plowing the snow after a 4-inch snowfall, using 40 horses, will be $135.00, at the rate of $6.00 per 8-hour day for team and driver; in case of a 6-inch snow, the cost will be $162.00, 48 horses being used.

THE COST OF PLOWING SNOW OFF DRIVES CLEANED ON THE SECOND DAY

	Per mile.	Per 1,000 sq. yds.	Per cub. yd.	Total cost without overhd.)
For 4 inch snowfall......	$8.31	$.378	$.00340	$135.00
For 6 inch snowfall......	9.98	.453	.00272	162.00

Third Day. (*Nine Hours' Day*)—One-half of the teams will plow snow to the sides on the following drives:

	Width, feet.	Area sq. yds.	Length, miles.	Cubic yards of snow on drive.	
66th and 67th Streets (Jackson Pk. to Ashland)...........	28	67,518	4.10		
Normal Avenue...............	32	63,580	2.10	at 4 in.	at 6 in.
Other half of the teams will plow:					
Grand Blvd. (side drives)....	25 each	58,432	4.00	together	
Washington Pk. (rest of outer circle of drives)............	40—50	45,000	1.60		
Total		234,530	11.80	26,060	39,090

At the rate of $6.00 per 8-hour day for a team and driver, the cost of plowing a 4-inch snowfall, using 40 horses, will be $135.00; for a 6-inch snowfall the cost will be $162.00. 48 horses being in use.

COST OF PLOWING SNOW OFF DRIVES CLEANED ON THIRD DAY

	Per mile of drive.	Per 1,000 sq. yds. of pavement.	Per cu. yd. of snow.	Tot. cost without overhd.)
For 4 inch snowfall.....	$11.44	$.576	$.00518	$135.00
For 6 inch snowfall.....	13.74	.692	.00415	162.00

By George T. Donoghue.*

Presented March 4, 1918.

The problem of snow removal in Chicago is a very complicated one. For instance, in the loop and in some of the business districts, all of the snow that falls on the sidewalks and streets must not only be cleared, but in addition, hauled away, while in the outlying districts and on practically most of our boulevards it is usually sufficient to clear the thoroughfare. When the snow must be removed, it can be piled in the adjacent parkways, thereby eliminating hauling.

To remove snow efficiency requires organization and proper equipment. In a good organization there should be a sharp distinction between snow "fighting" force and the snow "removal" force. Philadelphia and New York offer to us splendid examples of organization of this kind. In Philadelphia one engineer is in constant touch with the weather bureau. As soon as indications point to a continuance of the storm the snow fighting equipment is ordered out. Over 1,000 telephone messages are sent to squad leaders, foreman, snow plow drivers, laborers, etc. Attack is then begun with horse drawn and motor driven plows. Every man in this organization has

*Engineer of Lincoln Park, Chicago.

a particular function assigned to him. As an example, every foreman knows his post at a certain dump, and knows exactly what to do when he gets there. The driver of every snow plow and of every team knows where he is to report and what point he is to start to load, and at what dump he is to deposit his load. As a result of this preparedness there is no confusion.

Snow fighting: Experience has taught us that in fighting snow the best thing to do is to start when the snow begins to fall and work continuously, keeping abreast with the storm if we can. If we do not keep even with the storm and the snow becomes packed, the cost of doing the work is more than doubled. For snow fighting the horse drawn and motor driven plows under normal conditions have proved very effective. In Lincoln Park the experience has been that the horse plow should be pulled and the motor driven plow pushed. In the former case the abrasive action of the horses' hoofs helps to loosen and break up the snow, while in the latter case the snow is pushed to one side before the wheels can pass over and pack it down. The motor driven plow is by far the more efficient if it can be used before the snow is packed. After packing has taken place the motor driven plow has a tendency to ride over the packed portions, thereby not cleaning thoroughly. Under conditions of this kind slower but more effective work can be done by the horse drawn plows.

Snow Removal: Where snow has to be removed after being plowed, dump wagons and dump trucks are usually used to haul the material to the disposal stations. In Chicago, very effective use has been made of the lake and river for disposal purposes. In New York and St. Louis considerable use is made of sewers for carrying off the snow. Especially constructed manholes having large removable sectional covers are built and provided with a water jet having a pressure of 25-30 lbs. Where sewers are 2 ft. and over in diameter, this method has given very good results. However, there are very few sewers of this size in the park interiors, so this method is not available for the park forces.

The method of snow fighting and removal referred to covers the ordinary working conditions. The snow falls of January and February, 1918, were of such frequency and intensity that the usual methods of attack and removal had to be abandoned. In the January storm there was no chance to keep ahead of the snow. Motor driven plows sent out on the boulevards got stuck in the drifts and had to be hauled out with teams. The problem soon developed into one of snow *removal* entirely. The official government records show that 9 inches of snow fell in December—42.5 inches in January and 8.4 inches in February, making a total for three months of 59.9 inches. On many of our boulevards we encountered drifts from 6 to 7 feet high. Where 6 and 7 feet cuts are met they are out of the range of ordinary plow and scraper work. A steam shovel or drag line would be a more appropriate piece of machinery to handle a cut of

this size. Milwaukee was driven to the use of a steam shovel. On some of the narrow streets with car lines in this city there was absolutely no place left between the car tracks and the curb to place additional snow. Two steam shovels working nights were set to work loading snow into flat cars which were subsequently dumped into the river. The average cut on this work was between five and six feet. The dippers on these shovels were of the usual earth digging type. After watching them work for some time it was very evident that specially constructed dippers with larger capacity would have given a much larger output. In Lincoln Park we were not fortunate enough to have a steam shovel available for work. If we had one, I am sure we could have used it to great advantage. We were unable to get through the drifts with either our horse-drawn or motor-driven plows. As the plows went out of commission hand shoveling was the only resort left to open up the pioneer cut. In some cases the snow was cast aside and wasted, in others loaded directly into wagons. After this cut was made we brought into service on the boulevards a piece of equipment that we ordinarily use only when cleaning the skating ponds. It is a form of slip scraper made of wood and shod with iron. When fully loaded it has a capacity of more than ½ yd. The snow was gathered from the boulevards, hauled a short distance, and then dumped clear of the road. For the park problem this scraper was very efficient. Following the slip scrapers there was a battery of from three to five horse-drawn blade scrapers that pushed the snow towards the curb. Where it was possible these scrapers straddled the windrow left by the machine ahead. After the horse-drawn scrapers had done their work, the motor-driven plows followed them and made the finished cut. The outlined procedure was the one usually followed. In many cases it had to be altered to fit special conditions. The one outstanding feature in handling the February snowstorm was that it was necessary to reverse the usual method of procedure, sending the plows over last instead of first, and using the shovellers to open the path instead of trimming up after the path had been opened by the plows.

The city and park people did splendid work in removing the snow and have received a great deal of credit for what they did, but all of their work would have been in vain were it not for the gigantic work that was done by the street car men. For several days the only lines of communication between the outlying districts and the loop were the ones opened up and kept open by the Chicago Surface Lines. Public utility corporations are usually the target for much criticism, and it seems appropriate to me that at a meeting of this kind a word of commendation should be spoken in favor of the street car men.

By W. J. Galligan*

Presented March 4, 1918.

The problem of removing snow from Chicago's streets is about the same as it is in other large American cities located in the north in so far as it effects the business interests. Of course, local conditions change somewhat the manner and cost of removal, but as far as opening up the streets to traffic to conform to the demands of business is concerned, Chicago's problem does not differ from that of any other large American city.

On account of the emergency nature of the work and its high cost, snow removal is confined to certain designated areas, usually what is commonly known as the downtown section of cities. In Chicago for many years that area was bounded on the north by the River, on the south by Van Vuren Street, the River on the west, and Michigan Avenue on the east. The area was slightly extended from time to time, taking in Wabash Avenue and State Street as far south as 22nd Street; 22nd Street from State Street to Indiana Avenue, the principal thoroughfares in the 21st, 17th, 18th, and 19th wards, as well as Halsted Street from the south branch of the River to Lake Street.

As the City grew and larger appropriations enabled the Bureau of Streets to raise the standard of cleanliness for streets and alleys, the demand for snow removal service from outlying wards grew, and resulted in 1916 in a snow appropriation being made for each ward. These sums varied in accordance with the wards' needs and ranged from $500 and upward to the outlying wards, to $150,000 in the Loop.

It is a difficult matter to discuss the effective and economical removal of snow without making some reference to the disposition of municipal wastes generally. The shortage of funds, we are told, makes it necessary for the Aldermen who hold the City's purse strings, to deny to the Bureau of Streets the necessary funds for the purchase of adequate and up-to-date equipment.

The Vehicle Tax, which is a special tax that can be used only for the purpose of repairing improved streets and alleys, is able to purchase equipment, but as the street cleaning appropriations come out of the sadly overtaxed corporate fund, we have been unable to keep up to date in the purchase and use of the latest and best street cleaning machinery, and that condition is reflected more or less in our snow removal equipment.

One might say Chicago's snow removal service is divided into three classes—the Loop Section where all the streets and alleys are cleaned of snow—the Lower River Yards comprising the 21st, 22nd, 17th, 18th, 19th, and 20th wards, where the principal streets on which car lines run are cleaned, and the remaining outside wards

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where only intersections of street car line streets receive attention. At these corners, a space 50 feet each way is cleaned principally for the convenience of street car passengers in transferring from one car to another. We also try to give special service to churches and other public buildings, at the discretion of the ward superintendent. In case of heavy snow, the ward superintendents are also required to scan the death notice columns of the daily papers and to clean in front of the homes to facilitate the handling of funeral processions. When one stops to consider that each ward in area and population is a large city in itself, the meagerness of this service can be appreciated. Each ward has its business center, its own little Loop district so to speak, and the business men of these communities are growing more insistent each year that snow removal service be extended to their respective communities, and in view of the fact that each year our obligations are increasing, and since 1916 our appropriations decreasing, it can readily be seen that our position in the way of satisfying the public demands is not an enviable one. This matter took definite form during the present Winter in the forming of an organization that purported to represent the business interests in the outlying wards, demanding that snow removal service be given to them instead of spending the greater bulk of money in the Loop territory. They went so far as to threaten Court proceedings to bring this about. Of course we were unable to comply with their demands although recognizing the justice of their position.

The final disposition of snow when removed from streets in the outlying wards is growing each year a matter of greater worry to the officials of the Bureau of Streets. Heretofore we have dumped it in vacant lots and other places that would permit of a short haul, and as the area to be cleaned will grow greater each year and the dumping grounds grow correspondingly less, the problem of economical disposition is an ever increasing worry to our officials. The matter is one that should invite the serious attention of the City's Engineers and in my opinion should be considered in constructing the sewers of the future. Snow should be disposed of rapidly and economically by way of specially constructed openings leading to sewers large enough to handle it. Unfortunately, at present Chicago's sewers, except in a few instances, are not available for use in snow work. Countless appliances have been designed by the inexperienced looking toward the effective and economical removal of snow, most of them dealing with some form of melting process, and I dare say the patent office at Washington is cluttered with the records of these devices, but as far as I know, no demonstration has ever shown any of them to be practical. For many years the Loop territory has received snow removal service of varying degrees of efficiency. The practice was, in the event of a snow fall, to call in the ash teams from the outlying wards within a 3 mile radius of the Loop, and engage an additional number of outside teams as the

situation would warrant. An organization of picked men from outlying wards was formed and the Loop divided into districts, each district in charge of a ward superintendent. The names, addresses, and telephone numbers of this emergency snow force, grouped by police districts, were furnished the chief operator in the Police Department, and he in turn sent the lists to the different police stations where they were kept on file. In the event of a snow storm necessitating a night call, the superintendent of the First ward simply notified the chief operator in the Police Department to call out the emergency snow force and in that way the organization is easily and quickly marshalled.

With this organization we were able to clean the Loop in a fairly satisfactory manner although the emergency nature of the work makes the cost high, the costs varying, of course, with the nature of the storm, the depth of snow fall, the temperature, and the opportunity to get men, etc. It has been our experience that good results can only be obtained by constant and close supervision of the forces generally available for snow removal work. The work must of necessity be carried on under adverse weather conditions and consequently there is more or less shirking by men and teams in spite of all we can do.

The work of snow removal in the loop is carried on from the first ward yard situated at the foot of Randolph St. just east of Michigan Ave. where the emergency forces gather, are made up into gangs and are sent out. The quarters are inadequate for the orderly assembly and sending out of such forces, it being necessary on many occasions to secure the services of two mounted policemen as well as four or five officers on foot to keep even a semblance of order and to prevent the mob from breaking down the doors.

Numbered snow time cards are issued bearing the name and address of the holder. These cards are taken up when the men are sent out, and are returned to the men when they come in. The time is kept from these cards. A list of these card numbers is furnished each gang foreman, and in that way he is enabled to check his gang several times during the working period, a process we find very necessary.

The teams and trucks are handled in much the same way. The team tickets in addition to bearing the name and address of the holder also contain numbered marginal spaces for punching the number of loads hauled, a punch being given when the load leaves the street and again when it is unloaded at the dump. Tickets are made up in two colors, one for day and one for night.

Of course the blizzard of January 6, followed by the storm of January 12, will stand alone in the annals of street cleaning records for severity and accompanying unfavorable weather conditions. We saw at once that the ordinary methods of removal such as I have described, would not do in the face of this unprecedented storm, so we quickly cast about for some other means to handle the diffi-

cult situation. As the city budget did not carry a provision for the employment of motor trucks in this work, consent was obtained from the City Council to use motor trucks and the rate fixed at $25 for a nine-hour day. Only dump trucks of large capacity were used. The trucks were made up into squads of ten each. Each squad in charge of a ward superintendent, a card puncher and two sub-foremen. Five loaders were assigned to each truck. In that way trucks were quickly loaded and kept moving, and by working day and night shifts the principal streets in the loop were cleaned in 72 hours. For the reason that transportation lines were scouring the haunts of labor, bidding as high as $1.00 an hour and meals, and because of the extremely cold weather, it was difficult to keep men, and to compete somewhat with the other agencies that were bidding frantically for help, we picked out the likely looking material, kept them for the night forces and paid them time and a half which amounted to $3.97 for eight hours. In addition, on the coldest nights we sent around hot coffee and sandwiches, which were distributed to the gangs under the direction of a hastily organized commissary department. How much this service was appreciated might be shown by the fact that on two occasions gangs that had been in some way overlooked by the coffee truck, brought their tools to the ward yard at midnight refusing to continue work further.

The employment of motor trucks in the work of snow removal has shown to the officials of the Bureau of Streets that the results obtained by their use is far superior to that of teams. The large amount of creosote block pavement in the Loop made the handling of teams extremely difficult. Unskilled drivers and poorly shod horses made the task of proper maneuvering very hard and as a consequence traffic was constantly interrupted. Transportation officials will bear me out, I know, when I say that fifty teams poorly handled at stragetic points in the Loop will tie up Chicago's street car traffic in five minutes in a way that may take hours to untangle. With motor trucks no such situations were encountered. The limited dumping spaces handy to the loop is also a strong factor in favor of the employment of motor trucks. The Graham and Morton dock at the foot of Wabash Avenue is the largest Loop dump, and it will accommodate about 75 teams. At the height of a snow dumping day or night this spot was a bedlam of yelling, cursing drivers with the work being often interrupted by staggering and falling horses. It was also necessary to shovel the snow from the tail end of the wagon into the river, while bottom dump wagons deposited their loads on the dock, making it necessary to re-handle it into the river. One motor truck will haul as much snow as five teams, and inasmuch as 66 trucks, equivalent to 330 teams, used the Graham and Morton dock in one night, the increased capacity of the dock by the use of motor trucks is obvious.

The 66 motor trucks came in and out of the dump without a minute's confusion or delay. We therefore find that with proper

and close supervision the use of motor trucks, for every reason that enters into the prompt and economical removal of snow from the downtown district is far preferable to teams, and as a consequence we will use only motor trucks in the future.

Contrary to expectation, the labor this year was fairly plentiful and of a high caliber. The suspension of building and allied industries threw many good laborers on the market and we were able to use them to advantage in loading trucks. The Italian laborers, who comprise 95 per cent of the regular street cleaning force, are as a rule too short and over-clothed to be efficient in that kind of work, were carefully excluded from the loading forces. The rapidity with which the motor trucks operated is indicated by the record of Jan. 29, a typical night at the Graham and Morton dock, when 680 loads of snow were dumped in the River by trucks in 480 minutes, an average of one load every 45 seconds for 8 consecutive hours. It might be of interest to note that the record of delivery at the dock was distributed as follows:

Hours Between	Loads
6 and 7	118
7 and 8	96
8 and 9	76
9 and 10	70
10 and 11	97
11 and 12	85
12 and 1	75
1 and 2	63

You will notice the number of loads decreased as the vitality of the loaders ebbed until after the time coffee and sandwiches were distributed when it took a strong upward turn.

During the blizzard of Jan. 6 and 12, we hauled out of the Loop 14,611 wagon loads of snow, or 67,202 cu. yd., together with 5,644 motor truck loads containing 44,179 cu. yds., a total of 20,255 loads of 111,381 cu. yds., at a cost of $61,004.11. The cost averaged 54c per cu. yd. This sum seems insignificant as contrasted with New York's expense of $2,500,000 in a single Winter, a sum greater than the combined amounts spent in Chicago for the removal of snow, the cleaning of streets and alleys, and the collection of garbage and refuse.

The 16 City owned auto trucks in the Vehicle Tax Division are also used in snow work. Last Winter 4 of these trucks were fitted with snow plows so designed as to be readily attached at the required angle to the front of these trucks and this year the remaining ten were equipped. Schedules were laid out for the opening to traffic of certain thoroughfares before they could be reached by the regular snow removal gangs, and we were also enabled to open many streets leading to freight houses and railroad yards that ordinarily would

not get snow service. The plow squad is made up of experienced men and is ready for duty on short notice day or night.

I want to take the opportunity at this late day to congratulate the South Park, the West Park, and the North Park organizations for the splendid way in which they met the almost insurmountable difficulties of the January lizzards. I fully realize the immensity of the task that was theirs in opening miles of Boulevards and Park drives as well as walks. The Surface Lines, too, met the situation squarely in the face and by hard and intelligent work kept their main arteries fairly well open, and these open arteries I might add, enabled dazed Chicago to regain its equalibrium.

No record of the handling of the recent blizzards would be complete without the mention of the tireless efforts of our forces, from the Superintendent of Streets, who was on the ground day and night, to the ward superintendents in charge of truck gangs, who sacrificed their comfort and braved the elements long hours of the day and night in giving to the City a full measure of service, in order that Chicago and her thousands of visitors might not be inconvenienced, and in an effort to interrupt as little as possible the traffic of a great city.

March, 1918

UNIFICATION OF LOCAL GOVERNMENTS AND THE CITY MANAGER PLAN FOR CHICAGO

Presented January 7, 1918.

By George C. Sikes.*

Engineers, of course, have the same responsibility as other citizens for helping to promote good government in communities in which they live. They have also a larger responsibility in such matters than have ordinary citizens because of their training and their greater ability in thinking wisely on public problems. They should have a greater interest in the general efficiency of governmental systems, too, because in their professional capacity they so frequently come in contact with governmental agencies. Governments managed on the basis of efficiency invoke the aid of capable engineers much more frequently than do those operated on familiar political lines. It is highly significant that in City Manager cities engineers are often called to the post of City Manager. Mr. H. M. Waite, the City Manager of Dayton, had been the City Engineer of Cincinnati before he was called to Dayton as City Manager.

Major General George W. Goethals, the engineer who built the Panama Canal, because of his experience in that task and because of his study of the subject, has become a believer in the City Manager Plan of government for American municipalities. In building the Panama Canal, General Goethals was confronted with problems of government and of sanitation that were even more difficult to solve in many ways than were the problems of engineering encountered. General Goethals applied the direct processes of his well trained mind to the problems of government involved in such a way as to produce a simple and efficient system of administration. In an address delivered on March 17, 1917, in Cleveland, Ohio, before a committee of citizens considering the subject of governmental reorganization for that community, General Goethals declared himself a believer in the City Manager Plan of government. He said: "I became interested in the subject because I was offered the City Managership of two cities, and I read up on the subject, and the more I read on it the more firmly I became convinced that with the proper City Manager we approach more nearly the ideal form of government. It concentrates responsibility on the shoulders of one man who is hired for the purpose of serving the city, and it vests him with full authority. In most cases the legislative body consists of a commission, or a Council, or whatever you choose to call it, of five to seven men, selected from the city at large by citizens of the city, and these men hire the City Manager. The City Manager's business is to conduct the business of the city on strictly business principles, and if he is not satisfactory he is discharged and

*Chicago Bureau of Public Efficiency.

another man called in. The City Manager form of government permits the adoption of a continuous policy, which is not possible under our political form of government in cities."

The City Manager plan of government, thus strongly endorsed by General Goethals, is one that the Chicago Bureau of Public Efficiency is urging for Chicago.

The Bureau was organized in August, 1910. It is a citizen agency, supported by private contributions. Its function is to study the expenditures of local governing bodies in Chicago and to make recommendations designed to promote efficiency and economy. The Bureau began with the detailed study of particular offices, such as the office of Recorder, Sheriff, County Treasurer, the park governments, and departments of the city government. As a result of the studies and reports of the Bureau, improvements were effected in many offices. In some cases the heads of the offices welcomed the suggestions and acted upon them. In other instances the suggestions were ignored.

It was not long before the Bureau came to the conclusion that the greatest need of Chicago was the fundamental reorganization of its local governments upon the basis of unity, simplicity, and the short ballot. Under our present complex system it is impossible for local officials, even though they were all saints, to give the community really efficient and economical government. These officials might work greater improvement than they do, but there are many things which cannot be accomplished by independent governing agencies and officials each working in a separate field without co-ordination or central control. Chicago at the present time has 22 separate and more or less independent governing agencies. There are the County, the Sanitary District, the city itself, the three large park systems, and 13 small park districts. All of these governments are independent of each other. In addition, there are semi-independent governing agencies—the School Board, the Library Board, and the Tuberculosis Sanitarium—for each of which there is a separate tax levy, though these agencies are closely related to the city government because their governing boards are appointed by the Mayor, with the confirmation of the City Council, and their tax levies must be made by the City Council.

In the report of the Chicago Bureau of Public Efficiency on the Unification of Local Governments in Chicago, published in January, 1917, the Bureau urged the consolidation of all these governing bodies into one. It went further and urged the enlargement of the unified city so as to take in Evanston, Oak Park, and the other settled territory comprising metropolitan Chicago. The Bureau would have the agricultural portions of Cook County detached from the consolidated City and County of Chicago and it would have the detached parts annexed to adjoining counties. The Bureau has suggested that the boundary lines of the enlarged and unified Chicago should be substantially those of the present Sanitary District of Chicago.

Having arrived at the conclusion that the entire area within

what might be termed metropolitan Chicago should be brought under one local government, the question arose as to the best form of government for the unified municipality. It would be possible, of course, to merge all the other local governments with the city as now constituted, under which there is an elective Mayor and an elective Council, each more or less independent of the other, and the two often pulling at cross purposes. The Bureau went into this matter quite fully. It made a study of the trend of municipal government in the United States and in other civilized countries. It came to the conclusion that the best form of government for a city is that described as the City Manager form. This plan is in use in perhaps 75 cities and villages of the United States, the largest being Dayton, Ohio, with a population of about 150,000.

The City Manager plan of government as used in American cities is the commission plan substantially as originated in Galveston, with the manager feature added. The commission plan of government was an improvement for smaller cities over the Mayor-Council plan that had been in use previously. It is not theoretically sound, however, and in larger municipalities in which it has been tried it has revealed weaknesses. Under the commission plan, as used in Galveston, Des Moines, and other cities, the powers of legislation and administration are vested in a small commission, usually of five members, each of the commissioners being a department head. The presiding officer of the commission is usually called the Mayor, but he does not have the veto or appointing powers possessed by Mayors in American cities generally. Ordinances are passed by a majority vote of the commissioners, sometimes subject to popular referendum features, and appointments are made by the commission rather than by the Mayor. Each commissioner is a department head. This is where the trouble arises from the commission plan. There is danger that each department head under a system of courtesy and log-rolling will be permitted to manage his department as he pleases without interference from the commission as a whole. Under the City Manager plan, or the commission manager plan, as it is more commonly called, the commission is the repository of both legislative and administrative authority but the administrative power is exercised through a manager selected by the commission and subject to removal at any time, just as the manager of a business house would be. This plan is simple and logical and in nearly every place in which it has been tried it has given satisfactory results.

Well governed cities of the world outside of the United States for the most part have long had what is the City Manager plan in fundamental essence, though they do not use that term. In cities of England, France, Germany, and Australia, the people do not as a rule select administrative officials. They vote only for members of the local legislative body and that body is the repository of administrative as well as legislative powers. It administers usually through an agent or agents of its selection. American business

corporations and American universities are managed much in the same way. The stockholders of a business corporation choose the directors and the board of directors names the executive officials. The status of a university president is much like that of a city manager.

Thus the City Manager plan, as it is called in the United States, is not new, but really represents a return to first principles, both of city government and of business. Originally, American cities had substantially this form of government. Prior to the adoption of the federal Constitution, New York and Philadelphia, to take but two illustrations, had governments corresponding in form much to the government of a British city of today. There was no elective Mayor. All the power was vested in the City Council which administered either through committees or through executive agents of its selection. Following the adoption of the federal Constitution, American cities gradually abandoned their simple forms of government and imitated the federal model, with its division of powers and checks and balances, without much thought as to whether that plan was designed to meet city conditions. The checks and balances grew more numerous rather than fewer, with the result that cities in the United States today for the most part have systems of government far more complex than is that of the United States.

The Bureau believes a mistake has been made and that there should be a reversion to simplicity and centralized responsibility. Whatever may be said for the divisions of power and the checks and balances in the federal system, it is clear that they should not be applied as they have been to municipalities. Instead of a separation of the executive and legislative powers, there should be a mingling of the two under unified control. The Council as the policy determining agency of the government should also have supervision and control of the administrative agents that are to carry out the policies.

In accordance with this line of reasoning, the Bureau recommended that the unified government of Chicago should be of the City Manager type. The essence of the City Manager plan is the merging of legislative and administrative authority in the City Council, in which is vested the selection and continuous control of the executive agents. It is immaterial whether this legislative body be a commission of five members elected at large or a Council of greater size chosen by districts or wards. For smaller municipalities the commission elected at large is probably better, but the Bureau believes that for large cities the Council should have more than five members and that the method of selection by wards is the better one. For Chicago, the Bureau recommended a Council of 35 members, one from each of 35 wards, elected for four year terms, subject to popular recall. The plan of the Bureau of Public Efficiency calls for the selection of the Mayor by the Council, the Mayor to hold under indefinite tenure and to be subject to removal at any time.

This Mayor, who would be virtually a Manager, would have the appointment of heads of departments, who like the Mayor himself would hold without fixed tenure.

The Chicago Bureau of Public Efficiency believes that the unification of all local governments in Chicago and the adoption of the City Manager plan of government would be productive of great benefits. It would make possible a businesslike administration.

Of course, the plan of unification as proposed cannot be carried out without extensive modification of the Constitution of Illinois. Therefore, the Bureau favors the calling of a convention to revise the Constitution of the state and hopes that the proposition to that effect to appear on the ballot at the elecion of next fall will be approved by the people. Execution of the plan of unification outlined must await constitutional changes. However, the City Manager plan can be applied to the city government of Chicago at once if the Legislature will pass a bill to that effect and if the people of Chicago will approve the bill on a referendum vote. In a report issued in October 1917, entitled "The City Manager Plan for Chicago," the Bureau has presented a draft of a bill on the subject which it will urge upon the Legislature of Illinois whenever it shall meet again. That bill calls "For the reorganization of the municipal government of the City of Chicago by providing, among other things, for the election of the Mayor by the City Council, and for the non-partisan election of Aldermen; by fixing the number of Aldermen at 35, one from each ward; and by extending the term of Aldermen to four years, subject to popular recall." The term "City Manager" is not used in the bill. For various reasons it seemed best to retain the title of Mayor for the chief executive officer of the city, but the Mayor for which the bill makes provision would be virtually a City Manager.

This bill, by eliminating three city elections in every four year period, would save the taxpayers of Chicago for election purposes an average of about half a million dollars a year for the entire four year period. The Bureau believes that it would result in increased efficiency and economy of city government of far greater importance than the saving of half a million dollars a year in the cost of elections.

The program of the Bureau is two-fold in nature: ultimate—complete unification of all local governing agencies in metropolitan Chicago into one government of the City Manager type; immediate—the application to the City of Chicago of the City Manager plan of government. We are urging this two-fold program upon the community, and would like the help in furthering it of civic organizations. We would especially like the aid of bodies like the Western Society of Engineers.

DISCUSSION

C. D. Hill: I think this subject is of interest to engineers from the standpoint that the office of the manager of the city is one that

is particularly appropriate for engineers to fill. But I would rather discuss the political feature as it would be applied in the City of Chicago. I have had the opportunity for more than twenty-five years of watching very closely the operations of the government in the City of Chicago and I have quite definite opinions on the subject, based upon that observation.

The policy forming body of the City of Chicago has been the City Council. It is true that at election time the Mayor tells what he is going to do or what he has already done, and he talks about matters of policy, but they are usually things that the City Council will be called upon to do or that the City Council has done. The Mayor can not carry out any policy in the City of Chicago unless he has the co-operation and sanction of the Council itself.

Sometimes, in order to carry out this policy he is obliged to use force, that is, influence which is more or less harmful. That has been shown in a number of cases. In other cases the Mayor has failed to carry out his policy because he couldn't get the majority on his side. Then we have had conflict and discord and a condition of Government which is not at all satisfactory.

The elector in voting for officials is nearly always interested in the question of policy. He is very seldom interested in efficient management of the office. It is a question of municipal ownership or the price of gas or something of that sort. You never hear of any talk to influence votes on the theory that the men that are employed by the city are going to earn their wages or do the work efficiently. The electors should elect the men who are going to determine the policy. On the other hand, the Mayor of Chicago, if he has nothing to do with the matters of policy, if he merely carries out the policy which is decided by the council, has quite sufficient to do. There are very few men in big business who have a larger business to carry on than the Mayor would have if he simply attended to the executive business of the City of Chicago; if he simply saw that the heads of his departments and their sub-heads and the employees were carrying on the work of the city in an efficient manner, and were carrying out the will of the people, as expressed by the Council. But as a matter of fact, in all the 25 years I have watched the City of Chicago I have seldom observed the Mayor doing anything of the sort. He has always been interested in either the question of policy of the city or the policy of the party to which he belonged.

The Council of the City of Chicago is not controlled by political factions and parties. There are too many factions and parties for any one of them to secure a majority of the Council. There has always been a working majority that has been composed of members of all of the factions and parties. And there have even been independent members, men who have been elected to the Council strictly as independents; perhaps as a Socialist or something of that sort, who have belonged to the working majority. This working majority generally has a definite policy. That is to say, during all those 25

years the City Council has been working along certain lines, developing policies, getting through with them, and developing other policies. And this working majority is a continuing body. It isn't changed very materially at election time. A sufficient number of aldermen are re-elected and the men who are re-elected have more influence than the other aldermen, as they have had more experience. They secure positions on the important committees, so that this working majority is really quite an efficient body. There have been in the press at different times criticisms of the City Council. Sometimes the criticisms have been too severe. Sometimes they were perhaps justified as to certain individuals, but I doubt whether any legislative body in this Country has a higher average of intelligence for its work—the thing it has to do—that has higher standards of sincerity and honesty than the working majority of the City Council in the past 25 years.

The Mayor when he is elected either becomes the head of his particular party or becomes the head of the faction of that party. There is no use of going into details, but history shows that in the case of every man that has been elected Mayor, as soon as he is Mayor he then becomes or attempts to become, the head of his particular party. And as the head of that party he has very numerous political duties to perform.

When he becomes a partisan and deals with the City Council as a partisan, he stimulates a partisan reaction in the City Council, so that anything that he may propose, because it is proposed by the head of one faction will be opposed by aldermen who belong to other factions and other parties. If the Mayor attempts to carry on a partisan political Government he has to oppose a majority of the Council. That is because of the fact that the Council is composed of so many factions that only a minority is in harmony with a partisan Mayor at any given time. Without the partisanship of the Mayor the partisanship of the Council disappears, except possibly at the time of election.

A manager who is selected by the Council would not be a partisan, because he would represent the working majority, which, in itself, is not partisan. He would have to carry out the ideas of the working majority and he would have no duties outside of that. In fact if he attempted to play politics at any time he would antagonize the majority of the men who elected him. So it would be necessary for him to sustain the working majority. And if he tried to curry favor with this or that alderman he would get the enmity of two or three others probably. So he would devote his entire time to his executive duties. Then, if he was competent, he would probably remain in office indefinitely. We know that when there is a change in the office of Mayor there is always a great temptation to make a change through all the other departments, and such changes are made if they can be made. On the other hand, in the City Council, where the City Council itself controls the appointment of

committees, the men on the committees continue in office year after year in spite of the changes in the Council. The Council know these men, know they are right, and so they keep them there. I have no doubt that any man appointed by the City Council, if he did his work well, and was really competent, would continue just as long as he continued to hold their confidence. The same would be true as to the heads of his department. He would appoint men at the head of each department under him and naturally he would expect to keep them there as long as they did their work, and the longer they stayed the better they would do their work.

In closing I may say that I think if this plan were put into effect it would produce an enormous good in the Government of the City of Chicago.

Mr. H. W. Clausen, ASSOC. W. S. E.: I don't know that I can add very much to what Mr. Hill has said with reference to the operation of the City Government during the years he has had the same under observation. I have been connected with the city about thirteen years, and fully concur in what he says. It would seem that if greater efficiency in the City Government is to be obtained and better service rendered for the amount of money expended a change of some sort will be necessary. To illustrate what I mean it may be said that at the present time the City Council makes appropriation in the annual appropriation bill for all expenditures. This bill is very much in detail, making specific appropriations for each particular position. There seems to be a tendency, however, on the part of the City Council, where union labor is involved, to divert from this principle by simply advising that "Union scale" shall be paid. This leaves it to the department head to determine what the Union scale is. Very frequently officials in charge are unfamiliar with the workings of the Unions, and, again, being appointees of the administration, are as favorable to them as possible, which results in the labor organizations practically making their own appropriation bill. It would seem that this method of appropriation on the part of the City Council is illegal.

Another thing that is noticeable in the City Government is the fact that compensation for the more responsible positions is not anywhere near equal to that paid for similar responsibility in private life, while, on the other hand, the compensation of subordinate positions is slightly in excess of that paid by private concerns. The latter condition is proper, and should result in a better class of employes, which in a good many instances is a fact.

These conditions are no doubt the result of the fact that all votes are equal from a political standpoint, and, from the view point of numbers, the labor organizations and minor positions are in the majority. To the majority a compensation of $3,000.00 per annum and up would appear to be classed as a high salary. It accordingly follows, as before mentioned, that a reorganization of our City Government, possibly along the lines suggested by

the Bureau of Public Efficiency, must inevitably occur, if greater efficiency and better service are to be obtained for the money expended. It would seem to the speaker that fewer and higher calibered aldermen would achieve the result.

F. H. Cenfield, ASSOC. W. S. E.: I think the Chicago Bureau of Public Efficiency is to be congratulated on the study that has been made. One thing which should impress the Western Society of Engineers is the fact that they have gone after the fundamentals, which is necessary in order to correct the existing evils. The present system of government in Chicago is, as Mr. Sikes says, an outgrowth of conditions. We have been hampered by laws, and in order for the local community to progress along some certain line it was necessary to get a new law enacted. We found the Constitution had certain limitations, and we would probably get a new amendment which would give us that necessary authority. Chicago was limited in its power. In order to get around that limitation it was necessary to create the Sanitary District of Chicago, for a certain specific purpose. Later on it was necessary to create the Municipal Tuberculosis Sanitarium, for a particular purpose. When we go back to the fundamental proposition we can see the policy of our whole system of Government was fundamentally wrong. Mr. Sikes says it will take many years to carry out that program. There are certain things which can be done now, and for the information of the Western Society of Engineers I would like to call their attention to a resolution which was adopted on January 3 by a joint committee composed of five members of the State Senate and House of Representatives, and five members of the Committee on Finance of the City Council. The first two sections of that resolution has to do with additional taxing or licensing power. The third reads as follows: "That the term of aldermen of the said City of Chicago be extended from two to four years, with the right of recall after one full year of service. The said legislation to be subject to a referendum vote of the legal voters of the City of Chicago at the November election of 1918."

Fourth—"That the office of the City Clerk and City Treasurer be appointed by the City Council."

Over a year ago a resolution was introduced to the City Council providing for the City Manager plan, and public sentiment seems to be centering about that proposition, and sentiment in general seems to be pointing towards centralized authority, a reduction in the size of the Council.

It will take time to consolidate all the local governments and to crystallize public opinion. Those things won't come about much faster than the people will demand, and I think the Chicago Bureau of Public Efficiency is doing a great work in helping crystallize public opinion along these lines.

I think Mr. Hill pretty fully covered the matters of appointing a chief executive by the policy determining body of the City Gov-

ernment. There is no question but that we will be able to get men with a great deal of competence to consider an appointment by the City Council when they would not consider making a campaign, and I believe the City Council can be depended upon to select high caliber men.

That matter came to my attention a little over a year ago when one Council Committee had the duty of selecting a Subway Commission, and the way in which they attacked the problem I think would impress any one of the methods.

There are many other items in city government which the people should know. The city has just been completing a large intake tunnel, which surpasses in the matter of construction and the economy and speed of construction anything which has ever been attempted heretofore under contract. The city has had to take over one contract on that tunnel.

R. F. Schuchardt, M. W. S. E.: My contact with the City Government is only that of the "average citizen," but we "average citizens" know there is something wrong, and the reason we don't know more particularly what is wrong is probably the reason why it is wrong. That is, the conditions have just grown Topsy-like and in ignorance the "average citizen" has tolerated it. The Bureau of Public Efficiency has shown very clearly on the chart and Mr. Hill has also analyzed very splendidly for us, some of the reasons which make for the undesirable conditions in our municipal government.

The "average citizen" has been awakened by the great war and he is inquiring more why things are as they should not be and how can they be made as they should be, and he is also studying questions of public interest a little more. Therefore the work of the Bureau of Public Efficiency ought to bear good fruit at this time. The "average citizen" knows there must be some solution, and this solution of the Bureau certainly appeals to engineers. The engineer whose work is successful knows it must be based upon the proper use of common sense, and that chart certainly seems to be based upon common sense. As Mr. Sikes has said, the proposed program can be put over only if the citizens understand it and the need for it. The "average citizen" must be educated to knowing the faults of the present government and the benefits that would result from the adoption of the proposed scheme.

Engineers, some of them, are patting themselves on the back and saying, "The engineer is coming into his own. The war is being fought by engineers," etc. But, as a matter of fact, the average engineer is still pretty much in his shell, and it is only when he takes a personal and active interest in things of this sort that he is really coming into his own. I feel that the Western Society of Engineers owes it to the city in which it is located to do something at this time with this particular proposal of the Bureau of Public Efficiency.

DISCUSSION BY LETTER

Onward Bates, M. W. S. E.: The writer's name was coupled with that of Mr. George C. Sikes to speak on the subject of "Unification of Local Governments and the City Manager Plan for Chicago" at the meeting of the Society held January 7, 1918. He was unable to attend that meeting and takes this opportunity of tendering as a discussion of Mr. Sikes' address, some remarks he had intended to make at the meeting.

He wishes especially to bring before the Society the question of the propriety of considering this subject, and if this question is decided affirmatively he will ask the Society to make a public expression of its opinion. To make his position in the matter clear it should be stated that he is a Trustee of the Chicago Bureau of Public Efficiency and that it was at his suggestion Mr. Sikes was invited to address the Society. The object of our Society is "the advancement of the science of engineering, and the best interests of the profession." It is strictly an engineering society which provides for reading and discussing papers and matters of engineering, professional and social intercourse, the collection of a library, and the publication of its transactions. It cannot "endorse nor recommend any individual or any scientific or engineering production, but the opinion of the Society may be expressed on such subjects as affect the public welfare."

The writer has in past time been conservative, perhaps too conservative, in holding that the Society must limit all of its actions to engineering subjects. He still believes it would be adverse to the best interests of the Society for it to take part in partisan politics or even to act as a civic organization for or against public proposals in which our profession is not directly involved. There is, of course, the general exception to this statement, that when the public welfare demands action from all citizens, individually and collectively, they must respond to the limit of their resources. Unhappily, we face such a crisis at this moment when the winning of our war for righteousness is the first duty of citizenship. But for the ordinary questions coming before citizens it is best for engineers to act as individuals or as members of associations organized and equipped for their solution. We now live under new conditions, all men are questioning themselves as to where their duty lies. Societies of all kinds are considering their relations with the body politic. Engineering associations are appointing committees on public affairs. The terms "social justice" and "distribution of wealth" are used indiscriminately. In fact, there is a new awakening of public and private conscience, out of which good will come if sense and judgment protect the world from excesses. Many of us will have our convictions altered and will be found supporting principles and actions which did not formerly seem possible. The Western Society of Engineers recognizes in its constitution that it may have duties to perform for the public welfare. It may at this time very well go

farther and define the lines upon which it can and ought to express opinions for the purpose of influencing public action. It appears to the writer:

> That the Society may advocate or oppose public action on any proposal of an engineering nature, or so related to the engineering profession that the opinion of engineers are specially desirable, and;
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> That the Society should take no action, as a body, on any proposal that does not contain one or both of the above conditions, leaving its members in any case free to exercise the duties of citizenship according to their individual judgment, and:
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> That any action of the Society for the purpose of influencing public opinion should be for or against principles, and with strict avoidance of personalities or partisanship, and finally:
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> That any opinion promulgated by the Society should represent the views of the Society, as a body, and not simply the views of some of its officers, or of a committee, or of a small group of members present at a meeting. The opinion of the Society, to carry weight, and in justice to members, should be the opinion of its membership, based on information and with time for consideration. This means a referendum, which for lack of time or for other sufficient reason, may not be practicable, in which case if prompt action is necessary or desirable, it is incumbent on the officers of the Society to take the required action and to account afterward to the membership for such action.

The principles outlined above are similiar to those which pertain in the Bureau of Public Efficiency. The Bureau is a non-personal and non-partisan body and its reports are based on the painstaking work of the most reliable expert investigators it can secure. The data thus obtained are studied and discussed and passed on by the whole Bureau, and reports containing facts and recommendations are issued for the information, and for the purpose of influencing the public. So careful has the Bureau been to be accurate in its statements and figures, and sound in its conclusions, that the writer can state with satisfaction, some thirty odd reports representing seven years work of the Bureau have been treated with respect and commendation by citizens and by the public press. It may further be added that the Bureau's work has directly and indirectly resulted in large money saving to the city, as well as in improved business methods in the various city offices.

In the report on the City Manager Plan, which is before the Society, the proposed law was drawn with the aid of eminent lawyers practiced in the preparation of such acts.

Mr. Sikes' paper sets forth the need and the merits of this act and the writer will only call the Society's attention to the fact that city government is largely an engineering proposition and that

the employment of engineers is necessary in the conduct of the business of the city. It is not necessary to enlarge on this statement of facts already so well known to members of this Society.

It is to be remembered that the Bureau of Public Efficiency is only an instrument for obtaining facts and portraying them to the citizens, and that it is not clothed with any power, except the weight of its arguments, to carry its recommendations into effect. It is greatly assisted in introducing and making its reports useful by co-operation of the many patriotic and influential civic associations whose objects are the upbuilding of our city in all the ways which contribute to the welfare and happiness of its citizens.

In this instance the favorable opinion of the Western Society of Engineers, publicly expressed, is counted to be of special value, and is solicited by the writer who is a member of long standing and who would like to see the Society give the weight of its opinion to what he believes is for the public good.

PROGRESS IN THE APPLICATION OF CONCRETE TO BARGE AND SHIPBUILDING

J. E. Freeman, *Assoc. W. S. E.**

Presented February 12, 1918.

In many places today tribute has been paid to the memory of a great man—Abraham Lincoln. It is particularly interesting to recall that during the critical period of our nation's history in which he played such a memorable part, the battle of the Monitor and the Merrimac at Hampton Roads ushered in a new era in the building of the ships of war. Just so now when we are in the midst of another crisis, the development of reinforced concrete for the construction of cargo vessels, brings to the front a new method of shipbuilding.

The need of ships has become increasingly evident to all and that their construction in large numbers is a vital part of our war program is thoroughly understood. Judge George Gray, of Wilmington, Del., a member of the War Shipping Committee of the Chamber of Commerce of the United States, said recently in a plea addressed to the shipbuilders of the country:

> "There is no exaggeration in the statement that the necessity for an adequate production of ships is the most serious matter that now confronts us in this the greatest crisis in our country's history, or in the history of the world. We have entered this war for a just cause, and we must prosecute it with all our might and with all the resources of our country. Otherwise we cannot win it."

But speed is essential in securing tonnage, not only to replace submarine sinkings but to provide the great fleet of vessels required to transport and maintain an adequate army in the field and still continue to keep our allies supplied with certain necessities. We need this fleet in the quickest possible time. "Make a bridge of ships to France" is the latest message from General Pershing and his men.

The tonnage of steel and wood vessels now under construction in countless yards, to which is added ships transferred from coastwise and Great Lakes service, is still short of what is needed. To solve the problem requires the rapid development of another method of shipbuilding that will augment the tonnage under construction, and it is for this purpose that reinforced concrete is now being considered and utilized. The first seagoing vessel of concrete has made successful trial trips and vessels of larger tonnage are under construction both here and abroad.

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But there is another phase of the problem. Transportation of government supplies and material to the seacoast is taxing heavily the resources of the railroads. It is important that present inland waterways as well as our main highways be utilized to bear some of the burden and furnish a further means of transportation for ordinary commerce. In the words of W. W. Wotherspoon, New York State Superintendent of Public Works, "It is a patriotic duty to ship by water every pound of freight that can be so moved;" also, "At this critical period, the maximum use of every waterway is a national necessity."

Harbor facilities must also be increased to aid in transferring freight at seacoast terminals.

For all these purposes fleets of barges and lighters must be built, some of which can be utilized for coastwise or Great Lakes traffic, and in addition to the construction of self-propelled vessels thus fill the place of the ships transferred to trans-Atlantic service.

Concrete barges have already proved their usefulness on the Welland Canal and on Chesapeake Bay. They are being used in increasing numbers on waterways in England and France. It is reported that such barges are also in use on the English Channel for transporting military supplies.

Considering the situation it is only good judgment to develop the possibilities of concrete for ship and barge construction, especially in view of the fact that concrete materials are readily available in almost any locality desirable for the work, while the steel needed, as well as the labor required, is of such a character as to offer little interference with the proper development of the Government's shipbuilding program begun some months ago. The possibility of greater speed in construction is also an important factor, as well as the smaller plant equipment required.

The present speaker does not claim to be versed in the design of ships; that has been for many years the field of the naval architect and marine engineer. Barges and scows for use on canals, rivers and other reasonably quiet waters may not necessarily involve much knowledge of naval architecture, but in the ships and barges for ocean, coastwise, or Great Lakes service, special problems are presented with regard to strains to which vessels are subjected in a seaway and the development of proper lines for desired draft, speed, etc. To construct such vessels in concrete requires both the skill of the concrete engineer and that of the naval architect.

The concrete ship construction now under way in this country is of course largely experimental, assisted by experience gained in the design of steel and wood ships; but there is every indication of ultimate success, and, as has been the case in other

applications of concrete to new uses, experience with these first vessels will provide data to improve and clarify present ideas and to develop efficient methods of design and construction.

Those who have thus far worked out designs for concrete ships have done so more or less independently and up to the present only meager information has been published regarding the data and calculations upon which their designs are based. But recent advices in the technical press show that the Government is studying the problem, that a Department of Concrete Ship Construction has been formed by the Shipping Board, and is actively engaged in the development of a standard design for a concrete cargo ship of 3,500 tons capacity, drawings and specifications for which are expected to be ready in March; also that provisional contracts have been let to three companies for a number of 3,500-ton vessels, plans and specifications for which are to be approved by the Shipping Board.

This present discussion of concrete ships and barges, therefore, must of necessity be rather general, constituting a brief review of progress in concrete boat building from its earliest inception, some of the interesting work under way at the present time, and various problems entering into the application of reinforced concrete to such construction.

Singularly enough, one of the first uses of what would today be called reinforced concrete was in boat building—a rowboat built in 1849, by M. Lambot, of Carces, France, thus making the starting point not only of concrete boat building but also of modern reinforced concrete construction. This boat created considerable interest when exhibited by its builder at a world's fair in Paris in 1855 and was apparently in excellent condition as late as 1903. Records are lacking of any further development in France, however, until 1900, when a gravel barge, 50 feet long, 30 feet wide and 3 feet deep, was built on the River Lozere.

In 1899 Carlo Gabellini of Rome began the construction of concrete barges and scows in Italy and in 1905 a 150-ton barge was constructed for the city of Civita Vecchia. Later another barge was built for the use of the Italian Navy at Spezzia which before acceptance was put to the severe test of being driven against piling and afterward being rammed by a steel towboat. Up to 1912 about 80 vessels had been constructed by this concern.

Beginning as early as 1887 small concrete barges of 11 tons capacity were built successfully by the Fabrieck van Cement-Ijzer Werken, in Holland, followed later by larger craft of 55-ton capacity, having a cellular construction formed by longitudinal and transverse partitions or bulkheads reported as making the boat practically unsinkable.

In Germany a 220-ton concrete freighter was built in 1909.

The major portion of the hull had parallel sides, but was so shaped that the lines were fairly good and water resistance was decreased below that of a rectangular barge. This vessel also had water-tight bulkheads. It is reported that since 1914 Germany has built numerous concrete barges and some ships.

In 1912 a reinforced concrete scow or pontoon was built by the Yorksire Hennebique Contracting Co., Ltd., of Leeds, for maintaining work on the Manchester Ship Canal, in accordance with the requirements of the Canal Company's Engineers. The craft is 100 ft. by 28 ft. by 8 ft. 6 inches deep from main deck to keel, drawing about 6 ft. 6 inches when loaded to capacity (about 224 tons). It carries centrifugal pumps, steam winches, engines, boiler and coal supply.

Construction of the hull is a series of water-tight compartments so designed that if the exterior shell were destroyed, the body of the hull would still remain afloat. The compartment containing the boiler plant has a 4-inch floor and heavy beams supporting coal bunkers and boilers, but otherwise the general construction is light; the outer skin of the hull is only 3 inches thick. All water-tight compartments were carefully tested by filling them with water. The scow has been in almost constant service since construction with small expense for repairs.

In 1910 the building of concrete barges was undertaken on this side of the Atlantic. On the Welland Canal an 80-foot barge of 200 tons capacity called the "Pioneer" was built for maintenance work. Design and construction were carried out under the supervision of J. L. Weller, St. Catherines, Ontario. Engineer in charge of the canal work. The barge has a beam of 24 feet and depth of 7 feet; a rounded bow and square stern. The hull was divided into eight compartments by longitudinal and cross bulkheads, double hatchways at stern and openings through the cross bulkheads giving access to all parts. The deck, bottom, sides and bulkheads are 2½ in. thick, reinforced in two directions with ¼-inch steel wire and strengthened by the bulkheads and by beams and posts of reinforced concrete about 6 by 8 inches in size. Two 6 by 8-inch oak timbers serve as fenders. The barge draws 2 feet 8 inches light (130 tons displacement) and when loaded to capacity has a draft of 6 feet.

Since construction this barge has been in almost constant service with practically no maintenance charges and is still in excellent condition. At times she has been loaded with carloads of rubble stone dumped from a height of 12 to 15 feet directly onto the 2½-inch deck, the full load starting at one end.

On the Panama Canal three concrete barges 64 feet long, 24 feet beam and 5 feet 8 inches deep were built in 1910 to carry dredging pumps forming part of a plant used for hydraulic excavation at the site of Miraflores locks and were launched in

the spring and summer of that year. Reinforced concrete was used because it was impossible to obtain skilled labor and suitable material for the construction of steel or wood barges within the time required.

The walls and bottom were made 2½ inches thick—two 3-inch bulkheads extending from bow to stern making three compartments. Longitudinal beams at top and bottom of side walls and bulkheads with posts at 10-foot intervals, cross connected at posts by beams with knee braces, comprise the general framing plan. The shell was a 1:2 mortar plastered on the steel skeleton of rods and mesh. Interior members were 1:2:4 concrete cast in forms. The draft was 3 feet 5 in. with a total load of about 140 tons.

Following this work, in 1913 and 1916 a number of reinforced concrete pontoons were built at Panama to serve as landing stages for boats up to 65 feet in length, and have been in regular use since. These pontoons are 120 feet long, 28 feet wide and 8 feet deep.

While harbor engineer of Baltimore, Oscar F. Lackey developed a system of construction which was first used in 1909 to build a landing stage for small boats and then in 1912 was applied to building a 500-ton concrete gravel scow for the Arundel Sand and Gravel Co. of that city. This craft has a length of 113 feet, a breadth of 29 feet and a depth of 10 feet 6 inches.

Four longitudinal bulkheads and five cross bulkheads divided the craft into twenty water-tight compartments. The shell and deck were supported by a series of vertical and horizontal beams, the slabs varying from 3 inches to 5 inches in thickness, reinforced with plain bars running in both directions. The hull was built between forms and a very rich concrete mixture was used, with coarse aggregate of about ½-inch maximum size. With the intention of facilitating towing the sides were rounded on about a 6-foot radius and worked into sloping ends which were carried back much further than in the ordinary scow.

The scow has been in daily use ever since construction, is prefectly water-tight and has withstood the roughest kind of handling, requiring no pumping out. Light, the scow draws 4 feet 3 inches and when loaded to its capacity, has one foot freeboard.

The full rounded sides and ends developed some undesirable features under load in a high sea or strong wind and in berthing. Consequently, in two other scows that were built in 1913 and 1915, respectively, the design was more along the lines of the ordinary wood scow. These later scows were also cheaper to construct, form work being less expensive and placing of rein-

forcement easier. In the second, five longitudinal and five cross bulkheads were used, and a combination of bars and expanded metal for reinforcement. In the third scow an intermediate deck was introduced. The difficulties found in towing the first scow were eliminated and the draft reduced to 3 feet 10 inches. This was slightly in excess of a timber scow of the same capacity, but the concrete scow towed as easily when new, according to Mr. Lackey, and more easily than the other after a few months' service because of the lack of formation on the bottom.

One of these scows is used by the Raymond Concrete Pile Co., at Baltimore, a letter from whom last July stated that it had been very satisfactory in every respect and there had not been a dollar's worth of repairs since the scow was placed in commission.

Considering that these scows are water-tight, do not require hauling, scraping, caulking or painting, or maintenance other than repair to wooden fender system, and crediting the cost of time that would otherwise be lost in making such repairs the concrete scow becomes a decidedly interesting proposition.

England and France have recognized the utility of barges and self-propelled lighters of concrete. Last spring an English periodical mentioned a French company formed for the purpose of building sea-going concrete lighters; later pictures were shown of concrete boats under construction on the Paris Ship Canal. The Under Secretary for Sea Transportation and Merchant Marine in France was recently quoted as saying that very interesting experiments had been made with two concrete lighters in service. This has doubtless led to the building of more craft near Bordeaux, also several twin-screw vessels at Ivy-on-Seine of which recent press photographs give a general idea though details are lacking. An English paper reports orders on hand from the French Government for several hundred concrete barges. Several English firms have begun the building of motor-driven barges of concrete and more recently a concrete shipbuilding company has arranged for a yard at Dundee, Scotland.

Jas. Pollock & Sons Company, a London firm of naval architects and engineers, have drawn plans for a fleet of small coasting vessels of reinforced concrete, the first vessel laid down having a length of 92 feet, beam of 19 feet and depth of 10 feet. Power is obtained from a 120 H. P. oil motor. In coasting vessels which need not make over 8 miles per hour, the use of straight lines would not necessarily be a handicap and these concrete vessels have therefore been designed with such lines wherever possible to reduce form work, simplify bending and placing of reinforcement, etc. This firm is now drawing plans for larger vessels of 500 to 1,500 tons cargo capacity.

A letter just received from Victor Elmont, a former Chicago engineer, now in England, advises that he has recently designed a number of barges and sea-going vessels of reinforced concrete and is at present interested in the building of ten such sea-going barges of 1,000 tons capacity. It was recently stated by the First Lord of the Admiralty that ferro-concrete barges up to 1,000 tons were being built in Great Britain, which possibly refers to this same work.

A Spanish reinforced concrete cargo boat will be launched shortly by a corporation known as Works and Pavements of Barcelona, the first firm in Spain to engage in the construction of concrete ships. The length of the first vessel is about 110 feet, beam 23 feet and depth 11½ feet. Power will be supplied by a 120 H. P. Diesel engine and in addition sails will be fitted to the vessel. The company plans to construct during 1918 a gross tonnage of 40,000 in standard ships of 300, 500 and 1,000 tons each, while ground has been acquired to permit later the construction of 30 boats at a time, some of which are planned to be of 6,000 tons capacity. This company uses a mixture of 650 kilograms of cement to 1 cubic meter of inert materials (gravel and sand of three sizes), approximately a 1:2½ mixture, so as to obtain, in their own words "a dense, impermeable mixture that will permit also constructing the thinnest permissible section with a view to reducing maximum weight and thus obtaining the greatest possibilities in the way of speed." The concrete is considered to develop a compressive strength of 271 kilograms per square centimeter (about 3,850 lbs. per sq. in.) in 90 days and a working strength of 76 kilograms (about 1,100 lbs. per sq. in.) has been adopted.

Yet this work in shipbuilding is not entirely new, for Norwegian and Danish firms have already built and launched several concrete ships and self-propelled lighters of 200 tons capacity and now have larger craft under construction.

The Fougner Steel-Concrete Shipbuilding Company, one of the first in the field, has a plant at Moss established in 1916. The Company has built some eighteen or twenty reinforced concrete lighters and tow boats following successful experiments made by Mr. Nic. K. Fougner with a 50-ton concrete lighter at Manila in 1914. These lighters have capacities of 100 to 200 tons —the later types having more the barge shape. Some are in use along the Norwegian coast and others have been bought by the Norwegian Navy. A loading test recently reported of a 64-foot 100-ton lighter over an unsupported length of 40 feet showed a deflection of about 3/5 of an inch under a uniform load of 16 tons in addition to the weight of the lighter itself which was 58 tons. The surface is reported to have shown no sign of cracking or indication of flaws.

The structure consisted mainly of keelson and ribs of rein-

forced concrete with a thin shell of concrete plastered on expanded metal or cast around rods, and this method of construction has been applied to the first sea-going concrete ship, the "Namsenfjord". This vessel was launched last summer, given a high rating by Lloyds and is now in service for coastwise traffic. The vessel has a cargo capacity of 200 tons on a 9½-foot draft and is driven by a Bolinder crude oil engine of 80 H. P., giving a speed of about 7½ knots. The length is 84 feet, beam 24 feet, moulded depth 11½ feet. Larger ships of 600 to 1,600 tons are now building; but their general design is much the same as that of the "Namsenfjord" briefly described as follows:

There is a keelson of reinforced concrete with cross frames every 4 feet, the frames being continuous along sides and bottom and tide to the keel by the rod reinforcing. Particular attention is paid to continuity of reinforcement for these frames, and knee braces are provided at corner's of the hull. The skin is 3 inches thick reinforced with mesh and having a longitudinal beam at the outer corners of the hull.. Concrete-filled pipes are used for center posts at intervals. The hull is divided into water-tight compartments by transverse bulkheads of concrete reinforced with metal lath. The cabin is of wood and wood fenders are provided.

In building the hull, the bottom is cast in forms up to the top of the longitudinal hull beam previously mentioned. For the side of this size vessel the reinforcement and metal lath is set up for the total height and concrete deposited between the two sets of lath which act as a form; the outside and inside surfaces are then plastered. For larger boats this procedure is altered, using shorter heights of lath or casting the main frames in forms. Care is taken to make the construction continuous, however, so that no joints are left in surfaces exposed to water.

In the earlier craft a 1:1½:2 or 1:1½:2½ concrete was used with ½-inch maximum size aggregates, but later developments showed a 1:2 mixture with ¼-inch material worked better around the reinforcement.

The company has a contract for a 4,000-ton ore carrier 254 ft. by 40 ft. by 19½, equipped with two 300 H. P. Diesel engines and only awaits authorization by the Norwegian Marine Registry before proceeding with the construction. It has also constructed for a Christiana firm of yacht builders, a floating dry-dock of concrete—the first of its kind—with a lifting capacity of about 100 tons. This suggests another field for development in the present emergency, as our rapidly growing merchant marine will require many such structures.

The deck is 80 feet long, 38 feet wide and 20 feet high, with a sill 4½ feet thick and side walls 6½ feet wide at the bottom.

There are nine water-tight compartments. The dock accommodates a vessel 75 ft. by 25 ft. and is equipped with an electrically operated centrifugal pump by means of which a 100-ton load can be lifted from the water in one hour. The Fougner Company is reported to have plans for larger docks up to 15,000 tons capacity.

The ships built according to the Fougner system have a ratio of dead weight to displacement of from 12 per cent to 15 per cent less than for steel ships, that is, their displacement is more for the same cargo carrying capacity.

By dead weight is meant the cargo carrying capacity expressed in tons, usually in terms of long tons (2,240 pounds). The displacement of a ship is the weight of water she displaces and covers the weight of the ship itself plus the dead weight.

The Fougner Co. has established an American branch in New York and is reported to have a contract with the Shipping Board for several 3,500-ton ships contingent upon the success of the first vessel. It is stated that the Ferro-Concrete Shipbuilding Corporation of New York and the Liberty Shipbuilding Company of Boston also have similar contracts.

Another Norwegian company actively engaged in concrete boat building is the Porsgrund Cement Construction Work at Porsgrund. After the construction of a bridge pontoon in 1913, experiments were begun with a view to simplifying the form work and construction methods, as a result of which it was determined to build the boats upside down and launch them in that position. After successful experiments with a 9-foot model a 200-ton barge was built and launched last summer. The barge has a length of 98½ feet, beam 19½ feet and moulded depth of from 9 feet at center to about 10½ feet at bow and stern. It will be equipped with a 70 H. P. motor. Other lighters are in process of construction having capacities of 600 to 1,000 tons. The general design follows that of a framed steel ship. The righting of the boat took about 20 minutes, an ingenious arrangement of inner air-tight compartments making the craft practically self-righting.

The principle may be briefy described as follows: The inner mold is divided into compartments; when the vessel enters the water the air gradually escapes from the middle and upper two compartments through vent pipes, and the vessel losing buoyancy gradually sinks to a point of maximum submergence. The lower side compartments never being flooded, the vessel is in a state of unstable equilibrium, the center of gravity being considerably higher than the center of buoyancy. If the vessel now heels slightly to one side or the other a couple is formed the moment of which tends to turn the vessel on a longitudinal axis until she is righted and floats in correct position. The flooded

compartments are then pumped out and the molds removed to be used again for a similar vessel.

Progress in concrete shipbuilding has been made in Denmark also; one firm is reported to have several types from 300 to 1,000 tons d. w. approved and classified by the Bureau Veritas for overseas service. The work has even developed so far that Official rules have been laid down for design applying to the construction of flat-bottomed vessels of reinforced concrete.

At Montreal, the construction of a 126-foot ship of about 350 tons capacity was started early in September by the Atlas Construction Company, Ltd., and the vessel launched in November. This ship has a beam of 22½ feet and a depth of 12½ feet. The ribs are of structural steel encased in concrete and spaced about 27 inches apart, the steel sections being 5 inches deep at the top and 14 inches at the base. Before the plans were prepared by C. M. Morssen, President of the company, and Professor Ernest Brown of McGill University, tests on model ship beams were made to ascertain the resistance of concrete to some of the strains encountered in ship design. The shell is of reinforced concrete varying from 3½ to 5 inches in thickness and approximately 50 tons of reinforceing steel were used in construction. The concrete is reported to be practically a mortar, about 1:1½:1 with small gravel. It was placed between forms, construction being carried on as continuously as possible. The vessel is of the single screw type making about 8 miles per hour.

The concrete vessel to which probably the greatest interest attaches at present is a 336-foot, single-screw cargo steamship of about 5,000 tons capacity being built at Redwood City near San Francisco by the San Francisco Shipbuilding Company. The ship has a beam of 44½ feet and a moulded depth of 30 feet, with a designed load draft of 24 feet. She is to be fitted with Scotch boilers and triple expansion engine of 1,750 H. P., giving a speed of 10 knots. Fuel oil tankage is provided sufficient for 30 days steaming.

The hull is divided into nine watertight compartments by concrete bulkheads. The frames or ribs of the hull are spaced about 4 feet apart and there are also interior columns for the support of the two decks. The shell is reported to be about 5 inches thick at the bottom decreasing to 4 inches at the deck, which is about 3½ inches thick. In addition to the diagonal rod reinforcement in the shell, wire fabric is placed ¾ inch from the outside surface.

Concrete is now being deposited in the forms using a 1:1½:2 mixture with ¾ inch maximum size coarse aggregate and carefully graded sand. During the placing of the concrete the outside of the forms are hammered to thoroughly consolidate the concrete and produce a dense surface. After stripping the forms

the hull is to be sand blasted and given a coating of "gunite," later finished by rubbing.

Although several firms in New York City have been developing plans for barges, the first construction work of this character was begun by the Louis L. Brown Company last October; a 700-ton deck scow of length 112 feet, beam 33 feet, depth 10 feet and light draft 3 feet 4 inches.

The frame of the barge consists of reinforced concrete members supporting a thin concrete shell reinforced with wire mesh. Rail, bulkheads, and deckhouse are of concrete; wooden fenders will be used. Concrete is placed by means of a cement gun.

Construction of a 500-ton scow will be started shortly at Vancouver, B. C., the plans having been prepared by the Taylor Engineering Company of that city. This has an overall length of 107 feet, beam of 32 feet and depth of 9½ feet. It will draw 3½ feet light and 8½ feet when loaded to capacity. The truss method of framing is of interest. The same company is now designing a 1,200-ton well deck scow. A New Orleans sand and gravel company is now building a deck barge 130′ x 30′ x 7½′ deep of about 550 tons d. w.

In this connection mention should be made of the method of construction developed by Mr. Carl Weber, a member of this society, who has been studying the subject for some time. I understand that the method developed will be used this spring in the construction of a 65-foot barge for dredging marl and that later other work will be undertaken in the line of shipbuilding.

The method I believe, comprises the fabrication of the reinforcement for the hull by means of rods or light steel shapes and several layers of wire mesh upon which is built up the concrete shell by means of a special type of cement gun in which the mixture is first partially hydrated and then applied with compressed air.

A Joint Committee of the American Concrete Institute and the Portland Cement Association has been investigating this subject in a preliminary way, and recently prepared a report, covering points to be considered in designing concrete vessels and submitting a tentative design for a 3,000-ton seagoing barge of the following dimensions:

Length	227′ 6″
Length between perpendiculars	220′ 0″
Beam	42′ 0″
Depth	23′ 0″
Loaded Draft	18′ 0″

The displacement was estimated to be 3,675 tons on an 18 ft. draft. The vessel is divided into five compartments by transverse bulkheads, the three center compartments being for cargo and the other two for tank and ballast.

In designing, the criterion followed was a steel ship designed according to Lloyd's rules, and practically equivalent strength provided in reinforced concrete. A concrete of 1:1:2 mixture with carefully selected sand and selected gravel (about ½-inch size) was decided upon and considered to develop an ultimate crushing strength of at least 3,000 lbs. per square inch, allowing a maximum stress in concrete of 1,000 lbs. per square inch.

The spacing of the frames is 4 feet and the thickness of shell 4 inches on the sides and 5 inches on the bottom. Two lines of reinforcement are provided. The deck is 3 inches between hatches and along the lines of the hatches and 5 inches thick outside these lines.

An estimate of quantities gave the following:

Concrete	731 cubic yards
Steel	482,000 pounds
Flooring for Hold	30 M′ b. m.
Oak Timber (fender rail, etc.)	15 M′ b. m.

The total weight of ship was estimated to be 1,647 tons and the carrying capacity for 18 ft. draft 2,028 tons. The cost of the hull per ton dead weight was estimated at $63.00, best available figures indicating a cost of steel hull of the same character of $90-$120 per ton and the cost of a wooden hull $70-$100.

A few paragraphs from the report of the Joint Committee may be of interest in regard to points connected with the design of concrete vessels:

"It is apparent that the efficiency of a ship as a cargo carrier depends upon the relationship between dead weight and displacement. Expressed in terms of per cent., in the average cargo ship built of steel, the dead weight is from 70 to 75 per cent. of the displacement, taking into account as weight of ship all spars, fittings, deck houses, anchors and chains, auxiliary engines and tanks but not boilers, engines or coal. In a wooden ship, the dead weight is from 60 to 65 per cent. of the displacement. It is quite evident that from the difference in weight of materials, it will be difficult to design a ship of concrete that will give a relationship between dead weight and displacement approaching that of steel. However, if ships are to be built of concrete for commercial use, the weight of the ship must be such as to provide a reasonable dead weight or cargo capacity for the displacement.

"The stresses in the transverse members of a ship are, in still water, functions of the draft and the stiffness, and may be computed by mathematical processes, although the computations are long and laborious. When the material is reinforced concrete the problem becomes much more complicated. Experience has shown, however, that numerous elements other than draft affect the transverse strength of a ship, such as the effect of rolling in a sea way, impact with docks or other ships, and stresses inci-

dent to going into dry-dock. The transverse members of cargo ships of today are, therefore, not designed to withstand computed stresses, but are designed in accordance with various rules which embody the result of long experience in the construction and use of ships. It should be noted in this connection that granting of insurance depends on compliance with these rules.

"Steel ships are of two different types, (a) framed ships, in which transverse ribs of frames are spaced from 18 to 24 inches on centres, the plating being riveted to these ribs without intermediate longitudinal members, except in the bottom; and (b) longitudinally framed ship (Isherwood) in which heavy frames are spaced from 10 to 15 ft. on centers, with intermediate longitudinals to which the plating is riveted.

"From a comparison with the ordinary steel ship design, it would appear to be not difficult to design transverse members of reinforced concrete of equivalent strength to steel members—the question of strength only being considered.

"A ship must be able to meet conditions which are unlike any to which land structures are subject.

"In determining the longitudinal strength of a ship, it is customary to assume two conditions. Under the first condition, the ship is assumed to be suspended between two wave crests, the length between crests being equal to the length of the ship between perpendiculars, the height of the wave being equal to one-twentieth of that length. In this case, the ship as a whole is acting as a simple beam supported at the ends. This condition is termed "sagging." Under the second condition, the ship is assumed to be supported amidships on one crest of the same wave. Under this condition, the ship as a whole acts as a cantilever. This condition is termed "hogging." It is apparent, therefore, that when a ship is riding the waves both the deck and the bottom of the ship will be required to withstand tensile and compressive stresses alternately,—the maximum tensile stress following the maximum compressive stress at very short intervals. In a steel ship the entire cross sectional area of the midship section acts to resist these stresses, taking into account, in determining the moment of inertia, all of the continuous members such as continuous scantlings and deck, side and bottom plates. In the concrete ships, equivalent strength must be provided. In the case of the concrete ship, however, only the steel reinforcement can be relied upon to take tensile stresses. The concrete assisted by the steel, will take the compressive stresses.

"There is an almost unanimous opinion among naval architects and seafaring men generally that a concrete ship will be so inelastic that she will tear herself to pieces in a sea. While it is doubtless true that in a concrete ship there will not be the same readjustment of stresses as in a steel ship when subject to the

action of a heavy sea, experience with reinforced concrete structures generally has shown that such structures have considerable elasticity and there is ample reason for the hope that reinforced concrete will prove a suitable material for ship building purposes."

As to the possible effect of sea water on concrete, recent investigations by the Bureau of Standards as reported by Messrs. Wig and Ferguson throw new light on the subject and point out remedies. The results of their investigations tend to show that inferior concrete or concrete of which the surface skin has been impaired, suffers serious effects when in contact with sea water, and that great care in the mixing, placing, and finishing of the concrete is needed for durable construction. Judging also from their reports of structures in good condition, there is every reason to feel assured that the care needed in the selection and proportioning of materials and in mixing, placing and finishing concrete for concrete shipbuilding will provide the proper remedy.

With regard to the protection afforded the reinforcing steel the investigations of the Bureau of Standards show that portland cement itself is durable in sea water, which suggests that the rich mixture of concrete used in concrete ships, if properly deposited around the reinforcement will provide the requisite protective coating.

Besides the work now under way which has been mentioned, plans are nearing completion for the construction of other vessels on the Gulf and Southern Atlantic coasts so that in the course of six months there should be much more detailed information available on the subject. The art of concrete shipbuilding might be said to hold the position occupied by reinforced concrete fifteen or twenty years ago, but the knowledge gained during these years is helping to solve the present problems, and we may be sure of a rapid development in this hitherto unrealized field.

(Closure by the author. The questions and discussion brought out some details which are here considered and amplified.)

Whether the boat is built and launched upside down depends upon the depth of water available. When the vessel is turning over and has reached a vertical position, there must be a depth of water that will be somewhat more than half of the beam. A boat which has a beam of forty feet would need at least twenty-two foot depth of water for launching.

Judging from the reports received, placing the concrete for boats built inverted was done by a combination of two or three methods, partly in forms where the sides were almost vertical, partly by hand placing of the material and partly by placing the under air pressure.

With a rather liquid mixture the cement rises to the surface, thereby presenting a richer grade of concrete to the action of the sea water, but it is the intention in building concrete ships to use a rather stiffer mixture than is found ordinarily in concrete building construction, and to consolidate the cement, as referred to in connection with the San Francisco ship, by means of vibrating the outside of the form, which will not only consolidate the concrete and work it properly around the reinforcement, but will also form a very smooth skin on the outside, where it is desired to have the finish the densest.

Two or three different classes of aggregates are used in the concrete for the San Francisco ship. The aggregate used by the Fougner Company in Norway consisted of a mixture of sand and pebbles. In the construction of the barges on Chesapeake Bay an aggregate of about the same character was used. I see no reason why granite should not be used as an aggregate just as well as pebbles or trap rock or good hard limestone. The placing of the concrete is as nearly continuous as possible, the inside forms being more or less sectional to allow for inspection.

Some boat builders are using a compound to aid the concrete to resist the action of the sea water, and others are simply relying on the rich mixture and careful methods of placing concrete and finishing the outside.

The concrete ships do not require as much skilled labor as a steel ship. A great deal of the work of setting the reinforcement, placing the concrete, etc., can be carried out by cheaper labor, under skilled supervision. This is found in the construction of reinforced concrete buildings. This is a particularly interesting factor in the construction of concrete ships because it will utilize a scale of labor that will not interfere with the present construction of the steel and wooden ships.

The specifications for the ship at San Francisco require thirty days between the time of placing the concrete and launching. On the other hand, for the vessel at Montreal, the concrete was in place about three weeks before the launching took place.

There is little data available to give an accurate comparison of the amount of steel in a concrete vessel with that in a steel vessel but one might say roughly that the amount of steel in a concrete vessel would be perhaps half or less of that in a steel vessel.

The Joint Committee on Concrete Ships and Barges did not attempt to lay down any definite rules for design or definite specifications for construction, merely suggestions relating to the best concrete mixtures to be used and the best methods of placing the concrete, etc., as based upon present knowledge. The work which the Government is doing at the present time, however, in the department of concrete ship construction of the Shipping Board should develop a set of standards, I believe, leading toward a standardized design for concrete ships. They expect to prepare a set of speci-

fications to accompany the design which they will very shortly submit for concrete boats.

I believe that the Diesel and other similar engines are being used in this country also quite extensively, as the space required for fuel is less than that required for coal when steam is used.

The Namsenfjord was built in 1917, and at that time difficulties connected with the supply of materials, etc., were already being felt. A speed of seven and a half knots was attained, the boat being designed for that. The boat under construction at San Francisco is designed for a speed of about ten knots. That is largely a matter of horsepower. If a greater speed was desired it could be obtained by putting in a greater amount of horsepower, and also possibly by improving the lines.

I have been making a study of the storage of oil in concrete tanks and find a good many of these tanks have been constructed. Some of them are from six to ten years old, and by proper construction of the concrete and finish of the inside they are holding the heavy oils satisfactorily; that is, oils of gravity up to twenty-eight or thirty. For lighter oils it is necessary to apply, to the interior, some special coating which, we might say, is gasoline proof. A similar treatment of the interior of the concrete ship would make it available for carrying oils.

We are right at the beginning of this work in concrete ship building, and six months from now we will have a great deal more information available, not only as to the proper methods of design and construction, but also regarding the operation of concrete boats.

MEMOIR

Don Juan Whittemore, C. E., Ph.D.—M. Am. Soc. C. E.—M. Inst. C. E.—M. W. S. E.

Born December 6, 1830—Died July 16, 1916

Within the lifetime of Don Juan Whittemore the engineering profession progressed from an unrecognized and unorganized state to a first rank among those now established as learned professions. At the time of his birth there were but few broad-minded men who realized the necessity for increasing facilities of transportation and industrial production in this country and who had a vision of the advantages to be derived through improvements in machinery and transportation. Some of these few became our first civil engineers. They had foresight and natural ability, courage and perseverance, and were inspired by patriotism and ambition. At the date of his birth engineering was not a known profession. Those who practiced it and became its founders in this country were generally self-educated and skilled in some form of manual work, and by the increase of knowledge through acquaintance with each other's efforts. It was a year before his birth that civil engineering was first taught in a school and it was not until he was twenty-two years of age that the first organization of American engineers was established. This organization, of which Mr. Whittemore was later a most distinguished member, is the American Society of Civil Engineers.

Being actively engaged in engineering work from 1847 for more than sixty years and a close observer, he became a potent factor in bringing the profession of Civil Engineering to its present position of importance and usefulness. He was preeminently a railroad engineer, employed in railroad surveys, construction and maintenance, and as such did his full share, for a longer period than is granted most engineers, for the development of internal transportation. This is a sufficient field of effort for any one man and while it occupied his practical activity it should be recorded that he was always a discriminating student and a patient investigator and attained an unusual store of knowledge of a wide range of engineering.

A memoir of his life and work would be of historical and professional value if it could be fully and correctly written. Unfortunately for this record, it is found that his peers who could have supplied the data for such a memoir have preceded him into that country which is obscured from our vision, and it is left to the compilers to enter such fragmentary accounts as are now

NOTE: Memoir prepared by Charles F. Loweth and Onward Bates, for the American Society of Civil Engineers and the Western Society of Engineers.

March, 1918

available, and to supplement them from personal memory which does not reach backward to the early part of his working life.

A Brief summary of is life, dictated by himself in 1909 for family record, and not revised nor intended for publication, is introduced here for the reason that his own words uttered without restraint will be esteemed of more value than the words of another giving the same information:

> "I was born in Milton, Vermont, at a little hamlet called Checkerberry Green, December 6. 1830.
>
> "Parents: Father, Albert Gallatin Whittemore, lawyer. Mother, Abby Clark Whittemore.
>
> "My first school teachers were Sarah and Lovisa Wright (two giants in height, and mentally strong). Afterwards one 'Nerrit,' an Irishman and a famous instructor, followed by one Johnson, a collegian, and Dr. F. B. Hathaway, also a superior teacher. At about fourteen years of age my father placed me in school at St. Albans under the tuition of Friar Lawrence, so called. I also spent a short term in Georgia School. At St. Albans boarded at John Burgess'.
>
> "I then went to Bakerfield, where there was a celebrated school and teachers, the principal being Jacob Spaulding, a famous teacher. I remained there some time.
>
> "Great credit is due my father for his home instruction, he being a natural student, linguist, lawyer and surveyor. He took great pains in the education, morals and habits of his children. As I showed a fondness for mathematics and mechanics he secured me a position as surveyor on the Vermont-Canada R. R. (in last of 1847), extending from Essex Junction to Rouses Point, under Phaon Jarrb (a German), Division Engineer, the president of the road being Henry Campbell of Pennsylvania, at that time called 'Old Whitey,' being only forty years of age and white haired.
>
> "During this time the first trestle bridge ever built for railroads was erected on Missiquoi Bay between Alburg and Swanton, also a pontoon bridge at Rouses Point in 1849-50. Was Division Engineer at this time.
>
> "In 1851 went on to the Great Western Railroad, Niagara Falls to Windsor, with position as Resident Engineer.
>
> "In 1852 my father, being anxious to have me engage with the Ohio Central, he with others, under the firm name of Bradley, Whittemore, Thos. Chittenden & Co., I decided to visit him and see what the prospects of employment were, and whether it was best to go. November 10, 1852, the next day after my arrival, while my father and I were examining public works at Zanesville, by a fearful accident my father was deprived of his life and I barely escaped the same fate.
>
> "After his death and removal to the old home in Milton, Vermont, I returned to Ohio, after going back to the Great

Western to close my engagement there, and engaged with the Ohio Central Road leading from Wheeling, Virginia, to Columbus—over one hundred miles. My position there was contractor's engineer, representing the estate of my father, the company then being John Bradley, Norman L. Whittemore and Thomas Chittenden. I remained there from November to July, 1853.

"This company took a contract from Milwaukee to Portage City, now a part of the La Crosse Division of the Chicago, Milwaukee & St. Paul Railway, and I was then appointed assistant to the Chief Engineer, Byron Kilbourn, which position I occupied until 1857, when I left and engaged with the same company on the La Crosse & Milwaukee Railroad. Road failed, but company paid the debts—unable to go on.

"From 1857 to 1859 was Chief Engineer of the Southern Minnesota Railroad, running all over the state. This Company failed in 1860 and I went home in the spring.

"In December, 1860, went to Cuba and engaged on the Ferro Carril Del Oste, under Chief Julio Lagbien, as Assistant Chief. Road extended from Havana to Pinas Del Rio, western portion of the island. Returned to Vermont in April, 1861.

"Was married in Albany, New York (Brother Clark being present); afterward went back west and became assistant to the Chief Engineer, W. R. Sill of the La Crosse & Milwaukee until 1863. Soon the Chicago, Milwaukee & St. Paul was organized, when I was appointed Chief Engineer; the first President being Alexander Mitchell. Held this position forty-six years, Russell Sage, Vice-President part of the term; second President, Roswell Miller; third President, A. J. Earling.

"I conducted examinations through all the passes through the Rocky Mountains. About three hundred men, forty engineers. My present work—extension of the line to the Pacific Coast—the most important of all.

"On the St. Paul Road, east of Butte, Montana, are one hundred and seven miles of bridges, twelve tunnels, the longest one one-half mile. My part of the work extends from the Missouri River to Butte, Montana, under the name of the Chicago, Milwaukee & Puget Sound Railroad. I now have charge of about nine thousand miles of railroad.

"In 1884 was chosen President of the American Society of Civil Engineers.

"In 1889 went to England to attend C. E. Convention as Past President. Convention was held in London in Guildhall, a place where no other association had held exercises for two hundred years. Responded to the toast: 'The Civil Engineers.' Met Tyndall, the scientist, and many other notables, among whom was Sir William Armstrong, inventor of the Armstrong gun.

"After the convention travelled with my wife, son Eugene

and daughter Fannie through Switzerland, Germany, Brussels, France and England.*

"Second trip abroad was made in 1903 with my wife and niece Regia and visited Italy, Switzerland, France and England.

"On the 50th year of service on the St. Paul Railroad, to commemorate the event, I was, by order of the President, given a private car trip to Mexico and California with everything furnished, to which I invited my wife, and my brother's wife, son and daughter. A very enjoyable trip without serious accident.—D. J. W."

For about fifty years Mr. Whittemore resided in Milwaukee, Wisconsin, and in a "History of Milwaukee from its first settlement to the year 1895," there is found an account of Mr. Whittemore's work and personality, written about 1896, as follows:

"DON J. WHITTEMORE. In Volume XXI of the Transactions of the American Society of Civil Engineers, published some years since, Mr. Whittemore introduced the discussion of an important subject with this unique and strikingly original utterance: 'The scrap heap—that inarticulate witness of our blunders and the sepulchre of our blasted hopes; the best but most humiliating legacy we are forced to leave to our successors—has always been to me brimful of instruction.' The keen analysis of man's mental processes can hardly fail to discover in this utterance of one of the most famous of living civil engineers one of the secrets of his success. While looking forward he has not forgotten to look backward. While planning for the future he has not been unmindful of the past. Delving into the 'scrap heap,' he has uncovered mistakes to avoid the repetition of them, has brought to light blunders which he caused to be set up as guide boards pointing out the way not to go thereafter, and has garnered gems of wisdom to crown future efforts. Out of the ashes of failure he has evolved the phoenix of success, and in overhauling the debris of the scrap heap, it has been a matter of little consequence to him whether the errors exposed to view have been his own or those of some one else, so long as experience has demonstrated that they were errors. Blind dogmatism has had no place in his philosophy, and progress has been the rule of his life.

"To write of Don J. Whittemore all that might properly be written of him in this connection, would be to write an important chapter in the history of western railway construction and development. But the present purpose of the writer is

Note by Mr. Whittemore's brother: "A pleasant feature of the first trip abroad was the meeting of Prof. Tyndall. He gave Don an invitation to bring his family to a luncheon at his home, which was served in a small room or hut among the heather, which he and his wife occupied while building their house. Opposite was Mrs. Humphrey Ward, also near by was Tennyson's home. When they arrived he greeted them very cordially, even throwing his arms about Don, saying, 'This is my friend Whittemore.'—A. G. W."

rather to deal with the personality of the man who has attained a celebrity unequalled by that of any other man identified in a similar capacity with western railway enterprises.

"Born in Milton, Vermont, December 6, 1830, Mr. Whittemore is a descendant seven generations removed of Thomas Whittemore, who was one of the earliest settlers of Charlestown, Mass. Thomas Whittemore came to this country from Hitchin, an ancient market town in Herefordshire, near London, about the year 1640, and settled in that part of Malden which is now Everett, Mass. In 1645 he was the owner of a farm on the western border of Chelsea, which remained in the possession of his descendants until 1845, a period of two hundred years. Albert Gallatin Whittemore married Abby Clark, also of English ancestry, and Don J. Whittemore was the second son born of this union. The elder Whittemore was a noted lawyer of Milton, Vermont, participated as a volunteer in the battle of Plattsburg in 1814, was distinguished locally as a fluent and impressive public speaker and linguist, and a thorough mathematician. The son received his early education under the preceptorship of his father, in whom he had a most competent teacher, and later attended for a time Bakersfield Academy. Leaving school when he was seventeen years of age, he became connected with the engineering corps of the Vermont & Canada Railroad Company, and his proficiency in the science of civil engineering, even at that early age, is attested by the fact that when he was nineteen years old he was appointed Assistant Engineer of this company, having charge of construction of the line between Swanton, Vermont, and Rouses Point, New York. Having completed this work he was appointed Assistant Engineer and placed in charge of construction of a division of the Great Western Railway of Canada. He retained that position until 1852, when the sudden death of his father brought about a change of his relations. The elder Whittemore was at that time largely interested in the building of the Central Ohio Railway, between Zanesville, Ohio, and Wheeling, Virginia. He was accidentally killed while inspecting the superstructure of a bridge across the Muskingum River at Zanesville, and the responsibility of looking after his interests devolved upon the son, who happened to be paying him a visit at the time of his death. Resigning his position with the Great Western Railway Company, D. J. Whittemore became contractor's engineer on the Central Ohio Railroad, and retained that position while giving attention to the adjustment of his father's affairs.

"In this way he became interested in what was looked upon in those days as Western railway building, and in 1853 was transferred to the field of his future activity and enterprise in the Northwest. He was appointed that year assistant to the Chief Engineer of the La Crosse & Milwaukee Railroad Com-

pany, then in process of construction. At the end of four years in this service he resigned his position with the La Crosse & Milwaukee Road to become Chief Engineer and Director of the Southern Minnesota Railroad Company, locating about two hundred and fifty miles of that Company's line within the next two years. In 1859 work upon that line of railway was suspended, and broken in health by the hardships which he had endured in traversing a country then in a condition of primitive wilderness, Mr. Whittemore went to Cuba, where he accepted the position of Assistant Chief Engineer on the Fero Caril Del Oesta (Western Railroad of Cuba) with which he was connected nearly a year.

"Returning to Wisconsin in 1860, he again became Assistant Chief Engineer of the La Crosse & Milwaukee Railroad Company, continuing his connection with that company until 1864, when its line was merged into the Chicago, Milwaukee & St. Paul Railway System. With this great corporation, which now owns and operates over six thousand miles of railway, he entered upon a term of service as Chief Engineer, which has extended over a period of forty years, during which time the company has developed one of the great railway systems of the world.

"In the midst of his exacting railway duties he has found time not only for general scientific research but for special pursuits which have led up to important developments.

"In 1874, or possibly a little before that time, his attention was called to the hydraulic features of the rock deposits underlying a portion of this city (Milwaukee). He began a series of experiments, which developed the fact that a first-class hydraulic cement could be made from the rock. The result was the formation of the Milwaukee Hydraulic Cement Company, in which he became interested as a shareholder, and the establishment of a plant which now sends to the market upward of 500,000 barrels of cement every year. For many years he was a director of this company, but in 1891 he resigned this directorship to become Vice-President of the Western Portland Cement Company of Yankton, South Dakota, an enterprise of which he was also one of the founders.

"In 1884 he was honored by the American Society of Civil Engineers with the Presidency of that society, and the University of Vermont, his native state, has conferred upon him the degree of Civil Engineer; while the University of Wisconsin, his adopted state, has recognized his scientific attainments by conferring upon him the degree of Doctor of Philosophy. In the American Society of Civil Engineers he has wielded an important influence for many years, while he has also been conspicuously identified with the American Society of Mechanical Engineers, the Western Society of Engineers, and honored with

a membership in the Institution of Civil Engineers of England.

"In 1889, when a delegation of about two hundred and fifty of the civil and mechanical and mining engineers of America visited England, France and Germany, Mr. Whittemore was made honorary chairman of the delegation, and was the recipient of distinguished honors at the hands of the engineers and scientists of the Old World. Among the pronounced scientists with whom he became intimately acquainted on that occasion was Prof. Tyndall, and a friendship sprang up between the two men which resulted in a correspondence kept up until Prof. Tyndall died. As vice-chairman of the General Committee of the World's Congress Auxiliary to the Columbia Exposition, having in charge the conduct of the World's Congress of Engineers, held at Chicago in 1893, Mr. Whittemore had an opportunity to reciprocate the courtesies extended to him some years earlier while abroad, and he was a prominent participant in the deliberations of that famous gathering of engineers. A pleasing and ready writer, he has been a frequent contributor to the published transactions of the American Society of Civil Engineers, and now and then engaged to some extent in the discussion of important engineering problems through the newspaper press."

Among Mr. Whittemore's chief characteristics was an unusually retentive memory. He has been accused of remembering the exact location of every slope stake placed by him in the early part of his career when he was an instrument man. This is, of course, an exaggeration, but that quality of his mind is shown by the item copied below from the "Burlington Free Press and Times" of April 29th, 1887, printed forty years after the occurrence described:

"VERMONT AND CANADA ROAD"

"Where Its Construction Was First Begun—An Interesting Letter.

"We are permitted to copy the following from a letter written by D. J. Whittemore, Chief Engineer of the Chicago, Milwaukee and St. Paul, to his brother, A. G. Whittemore of this city:

" 'I notice in Rann's history of Chittenden county, page 191, it is stated that the work of constructing the Vermont and Canada Railroad was begun early in September, 1848, in the northern part of Georgia. If the author means to convey the impression that work was first begun there I feel sure that he is in error. The first ground broken in the construction of that line was at near the north end of the Y at Essex Junction. There were present at this ceremony Charles Paine,* president; H. R. Campbell, chief engineer; Phaon Jarrett, assistant chief engineer; Ambrose Pierson, first assistant engineer; ——— Bushnell, second assistant engineer; D. J. Whittemore, rodman, and several citizens of Essex. After a few impressive remarks on the

*Charles Paine, President American Soc. C. E., 1883.

importance of the work by President Paine,* he loaded one barrow with earth and wheeled it into embankment. Each of the others in the order named did the same, after which all adjourned to the office near by and drank a bottle of champagne. The shovel and wheelbarrow used were appropriately inscribed with the names of all the actors, in Captain Jarrett's best style of lettering, and I believe were sent to Northfield and presume were burned in the conflagration which destroyed the Vermont Central buildings three years afterward. It may be that I am now the only one living who participated in this event. This is of very little importance anyway, except to correct the impression conveyed in the work referred to.' "

In Mr. Whittemore's service of more than half a century with the Chicago, Milwaukee and St. Paul Railway he encountered almost every problem of railway engineering and was able to collaborate with those who had made particular study of special problems and to learn and apply the knowledge acquired by their intensive experience, to their mutual satisfaction. This was especially the case in the matter of bridges when, with the aid of such men as C. Shaler Smith, Moritz Lassig and others, the structures over the rivers crossed by his lines were of such character as to make them noted examples of correct and bold construction. A few such bridges may be mentioned here for the reason that they were constructed at early dates when long span bridges were rare, and builders were feeling their way toward present achievements. Kilbourne bridge over the Wisconsin River, a wooden Howe Truss structure with a principal span of 242 feet, carrying a highway on its lower chords and a railway on its upper deck, served its purpose and was replaced in 1887 by an iron structure, which in turn was replaced by a steel bridge a few years ago. Moritz Lassig was the builder of the wooden bridge, C. Shaler Smith of the iron bridge and the steel bridge was built by the Railway Company some years since.

Sabula Bridge, an iron structure over the Mississippi River was built by C. Shaler Smith about the year 1879. This bridge was at that date considered one of the best examples of such construction and it was selected by Professor Malverd A. Howe as an example for use in University instruction and was made by him the subject of a text book. This bridge was examined by experts a few years ago, who pronounced it of excellent design and well maintained but was recommended for replacement to provide for increased live loads from modern rolling stock. This recommendation has since been put into effect.

Minnehaha bridge, another iron structure built by Mr. Smith, over the Mississippi River at Fort Snelling, finished in 1880, was a deck bridge with a central span of 324 feet, two flanking spans of 270 feet each and some approach spans, with a height of 108 feet from high water to base of rail. It was similar in design to Mr.

Smith's cantilever bridge over the Kentucky River, which preceded it, and was considered a distinct advance in bridge construction attracting favorable comment from bridge engineers. The Minnehaha bridge was replaced in 1901 by a double track steel bridge. .

These bridges, while not comparable in size with the great ones of recent years, are worthy of record as advancements in the art of bridge engineering as it was thirty and more years ago. Mr. Whittemore's specifications for iron bridges written in collaboration with the bridge engineers of those days were classics in their line, leading the art of the time in form, completeness and correctness of theory and design.

Mention has already been made of Mr. Whittemore's connection with a pontoon bridge at Rouses Point in 1849-50, when he was scarcely more than a boy. It is not therefore strange when, some years later, it was necessary to cross the "Father of Waters" at Prairie du Chien, he accepted the proposal of Hon. Thomas Lawler of that city to cross both channels of the river with pontoons. For more than forty years these bridges with large openings for navigation have been safely and economically maintained, and have been copied at other locations.

In Mr. Whittemore's practice he had great experience with general railway contractors and employed many of the most notable of them. Nearly all of these men whose aid he secured are now dead. If they were living, material for this memoir could be gathered from them which would fill a volume of value to the profession. He commanded the respect of such aids and it is a notable fact that final settlements of contracts, with remarkably few exceptions, were made to the satisfaction of both parties, who accepted his rulings as just and fair. This fact, which will be appreciated by engineers of experience, was so well known that it is frequently commented on.

The diversity of work coming under his supervision was so great and the period of his office was so long that it is impossible to bring the details of it within the scope of this memoir. Mention should be made, however, of the careful and complete work which he did with his own hands. Specifications and bills of material made out in his own handwriting, which have been seen by the compilers of this memoir, are so plain and yet so complete that there is no question raised as to their exact meaning.

Mr. Whittemore was more than a railway engineer. He was a student and investigator in many lines and fields with a rare mind capable of seeing through to the end, and he employed his facilities in his leisure moments on a multiplicity of interests. Those who were with him at such times would be surprised at the questions he would ask and at the diversity of their character and would be instructed by his sage remarks covering a wide range of knowledge. He was on such occasions a source of instruction and an inspiration for younger men. On business trips over the lines of his company,

while not in the least neglecting the work immediately in hand, he would give his assistants problems which had no immediate relation to present work, but which were tests of their knowledge and of their capacity for considering new questions. This seemed a lifetime habit in educating himself, and one having close relations with him would observe with surprise the lines of study to which he applied himself, because they were foreign to the ordinary routine of his business. He carried with him this habit of study and reflection, and friends visiting him in his quiet hours would find him absorbed in Isaac Newton's "Principia," or in some abstruse problems more or less remotely connected with those encountered in his usual practice.

He possessed an analytical mind with a natural talent for research, and in the pursuit of knowledge he made in a quiet way valuable contributions to practical science. It was characteristic of him to be thorough in analysis and in experimentation, and always interested in the subject under consideration. Mention has already been made of his interest in the production of hydraulic cements and his successful establishment of that industry in the City of Milwaukee. This was followed by similar work resulting in the commercial manufacture of portland cement at Yankton, South Dakota, where it was successfully made at a time when portland cements were nearly all imported and none was made west of the Alleghenies. It is not possible to place a tangible value on his work as a cement investigator, but that it was of very great value in the development of a large section of our country is evident when considered in its relation to the magnitude of the cement industry of the present time.

He gave much attention to the production of aluminum at a period antedating its manufacture on a commercial scale, and while successful in extracting it, did not reach the achievement obtained by the method at present in use.

His investigations covered a wide range of subjects and, as might have been expected, some of his work resulted more in personal satisfaction than in practical value. An instance of this is found in the "Equilibristat" invented by him, being an instrument to be mounted in a railway car to indicate whether the super-elevation of the outer rail on curves is proper for the speed of the car passing over it. He exhibited an equilibristat and read a paper on it before the Western Society of Engineers.

Mr. Whittemore's loyalty to the railway of which he was Chief Engineer led him to consider the interest of his employer as his first and principal duty, and under that obligation he found little time to devote to personal interests outside of those pertaining to his office. Mention has been made herein of his interests in Milwaukee and Yankton cements and a large user of both of these cements testifies that he was unable to get Mr. Whittemore to recommend either of them even when the question was pressed for an answer. As a consequence of this policy he did not participate to any great extent in employment as a consulting engineer, and not

at all without the approval of his superior officers. He might have done more of such work without detriment to his employer and to the advantage of the profession if he had not had so scrupulous a regard for his fixed obligations. His long experience preserved by a retentive memory, with his judicial faculty of mind, was a valuable professional asset which ought to have been used more frequently for the general benefit. There were occasions when he had to yield to imperative demands for his knowledge and judgment. On two different occasions when disastrous accidents occurred to the bridge over the Missouri River at St. Charles, Mr. Whittemore was summoned to investigate and determine the causes of failure. No record has been preserved of his professional services aside from those rendered in his official position, nor of the requests for such services which he felt he ought not to accept. In the year 1888, he with Messrs. Joseph M. Wilson and A. P. Boller were appointed by the city of Providence, R. I., as a commission to investigate an important city problem, and much credit was given the commission for its report. In his long period of active practice there was without doubt much which could profitably be referred to in this memoir if the facts were obtainable.

Mr. Whittemore's interest in the advancement of his profession was shown by his active support of its societies in contributing to their transactions and in his labors on their committees.

The American Society of Civil Engineers admitted him to membership in 1872, made him a Director in 1881, President in 1884, and Honorary Member in 1911. The Western Society of Engineers, in which he held membership, honored him by election as Honorary Member. He was a member of the Institution of Civil Engineers of Great Britain. He was also honored by the University of Wisconsin with the degree of Doctor of Philosophy.

Mr. Whittemore was a clear thinker, with facility for expression as a writer and speaker. With a modest man, as he was, such traits lie dormant until developed and brought to light by circumstances. When it became known that he was a well informed and pleasing speaker, opportunities for speaking were so frequent that he acquired the habit of declining, and it was a rare occasion when he could be induced to make an address. He was urged by friends to write contributions to the history of engineering in this country, which with his long experience and observation he was well qualified to do, but he would not yield to their solicitations. His habit of reticence seemed to grow upon him with advancing age and it is much to be regretted that, when he began to lay down his routine duties, he did not contribute from his ripe experience for the benefit of those who had not acquired that which they knew he possessed. He departed this life after outliving all those with whom he worked in the "early days," and these men left mostly memories and traditions without actual records, but their work is not wholly lost for those whom they educated will pass their knowledge on through their

successors and what they accomplished while living remains an intangible asset for those who come after them.

Mr. Whittemore was by nature more an engineer than an administrator. If his administration duties had outweighed his others it is probable that he would not have limited his energies to the practice of engineering. He was associated with railway construction and maintenance throughout a lifetime covering the development of railroads from almost their beginning, and if his ambition had been in the line of railway promotion and management, it is altogether likely that he would have become associated with them as business enterprises rather than as fields for engineering effort. In other words, his work was professional instead of commercial in character. He must have had many opportunities for profitable employment as a contractor or a promoter, and it is characteristic of him that he appreciated his office of Chief Engineer and resisted temptation offered by more lucrative employment.

He understood the requirements of an engineering organization and his ability to discern character enabled him to gather about him efficient and loyal assistants and to employ competent contractors. His relations with all such were friendly and promoted the feeling of common interest instead of antagonism. As indicative of his character and of the esteem in which he was held by his associates the following extracts from letters, sent to the compilers, may be properly introduced in this memoir.

From Mr. E. O. Reeder, Assistant Chief Engineer, Chicago, Milwaukee & St. Paul Railway:

> "Although I served under and was very closely associated with D. J. Whittemore, as a subordinate, for the greater part of the time from early in 1875 until his retirement from active service in December, 1910, I find some difficulty in suggesting matter for his memoir.
>
> "Few engineers, or in fact few managing or directing officials of a railway company, have a record of such a close and direct connection from the beginning, with the building up of a great railway of the magnitude of the Chicago, Milwaukee & St. Paul Railway.
>
> "In the early 'fifties,' practically at the beginning of railway construction west of the state of Ohio, Mr. Whittemore was engaged on the surveys and construction of lines in Wisconsin, which were the nucleus of and are still a part of the C. M. & St. P. Railway System. I have heard him remark that he once surveyed a line across the site of the present heart of the City of Minneapolis and that no house or building was then there to obstruct his work.
>
> "From these early days until his death, except for a few short intervals, he was connected with our company, and for the greater part of this period he was the head of the Engineering Department, and as such he planned, directed and

supervised the construction of some 6,000 miles of new railway now forming a part of the great system of over ten thousand miles, and he also planned and directed the many works and improvements that were undertaken in developing the system.

"He held to a marked degree the confidence of the managing officers of the company, from S. S. Merrill, who, perhaps more than any other, laid the foundation of the system, to A. J. Earling, who extended and built it up.

"Mr. Whittemore's reputation for justness and fairness as between the railway company and its contractors was so high that his decision as arbitrator was seldom, if ever, questioned, and because of this high estimation the railway company was able to contract its work to the best advantage, and few, if any, controversies resulted in law suits in settlement of contracts.

"Mr. Whittemore's personality, character and high mental attainments commanded the admiration and respect of all who knew him. He possessed a strong and active mind.

"His subordinates loved and respected him and felt complete confidence that he would be just and loyal in his treatment of them.

"To me, among his most marked characteristics, were his power of concentrating his mind on and his ability to thoroughly analyze a subject. Physically he was not very rugged and consequently had to depend upon observations and reports of others for his knowledge of many operations and conditions, especially as regards examinations and explorations for new lines. He had, to a remarkable degree, the faculty of getting from reports of others a more complete insight and understanding of pertinent facts and conditions than an ordinary man would get from actual observation, and of thereafter retaining these facts in mind.

"His reputation as an engineer can best be commented on by some one who has a wider knowledge of it than I have. His contemporaries and associates in the profession were of the most prominent engineers of the country and of the world and his rank among them was high."

From Mr. A. G. Baker, Assistant Engineer, Chicago, Milwaukee & St. Paul Railway:

"I have to say that the following few lines relative to my personal estimate of Mr. Whittemore are submitted with diffidence as the subject is difficult to handle as it deserves. Having been intimately associated with Mr. Whittemore for twenty-five of the thirty-eight years of service with the Chicago, Milwaukee & St. Paul Railway, I venture to say that it is possible for me to form a fairly true estimate of his qualities as a man and engineer.

"As a man and chief I think there were few occupying the

position that he did, who had the quality of winning the respect and loyalty of his subordinates and in my case a degree of affection hard to express.

"On his part, he was loyal to his assistants who were deserving and tried to do their duty. In this respect, one of his chief characteristics was the solicitude he displayed for the comfort and safety of any one of his engineers sent on a specially hazardous undertaking in the line of reconnaisance or survey. Many instances of his thoughtful consideration along these lines occur to the writer and others will bear witness to the same.

"Another characteristic was his absolute fairness in dealing with contractors. His instructions were explicit to all engineers on construction work to treat all contractors from principals to sub-contractors and 'station men' with due consideration. All of the leading contractors in the West with whom I have had business relations concur in the general statement that they could safely leave all matters of classification, etc., to Mr. Whittemore, feeling sure they would receive just treatment.

"As to his qualities as an engineer it would seem superfluous for the writer to enlarge on his abilities, too well known to require endorsement from this source. However, it might not be out of place to mention one quality so often noticed, i. e., his ability to grasp difficult situations relative to location of lines, from reports and examination of maps and profiles, without having a personal knowledge of the country traversed, and to make valuable suggestions to the betterment of conditions. This quality was also observed in matters relating to construction. This point was called to the attention of the writer more particularly during the construction of the Puget Sound Extension. Mr. Whittemore had not been able to go over the new line until the track was laid and the line in operation. In 1910 it was the privilege of the several Engineers of Construction to accompany him in a business car over their portions of the work. While watching the line from the car he would frequently notice and call attention to places where particular difficulties occurred and were referred to him for advice and instruction; he having recognized them from his familiarity with the profile and map of such localities. His memory and "bump of location" were extraordinary.

"In his dealings with his assistants relative to their work. his fairness was proverbial. Where necessary, his criticisms were severe and he seldom failed to strike at the root of faults. In conclusion I can not refrain from stating that Mr. Whittemore was as much a father to me as a chief during the many years I served under him and my feelings of affection for him were strong."

Mr. Whittemore was a charming social companion—with rare

humor he could entertain his friends for an evening and make it an occasion to be long remembered. He was a good story teller and his reminiscences, based on the experiences of his early practice, were fascinating to younger engineers. His disposition was naturally a retiring one, and his friends greatly regretted that in the latter years of his life he seemed to avoid the gatherings of engineers. At the last convention of the American Society of Civil Engineers attended by him (held in Chicago in 1910) he told a friend, who met him at the hotel designated as convention headquarters, that he was too old, that he did not know those whom he was to meet and that they would not care to meet him. This friend arose to the occasion and privately repeated what he had said with the result that he was given an ovation by those of all ages who were present and for a short time was made to feel young again. The present generation will have to disappear before personal recollections of him will cease to be expressed.

He had a kind heart and, like many others who have that possession, he did not display it in public. Always helpful of others, his benefactions were not recorded. All his friends will remember him with warm feelings of regard and respect and will continue to speak of him as one of the early builders of our profession.

On December 6th, 1910, Mr. Whittemore retired from the office of Chief Engineer of the Chicago, Milwaukee & St. Paul Railway Company and did not thereafter perform any active duties, although he carried the honorable title of "Consulting Engineer" until the date of his death. He is survived by his widow and his daughter, who is the wife of Philip N. Littell, author and publisher, residing in New York.

March, 1918

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings.

MEETING NO. 997, MONDAY, MARCH 4, 1918.

This was a meeting of the Hydraulic, Sanitary and Municipal Section. There were present sixty members and guests. Mr. H. E. Hudson, Chairman of the Section, presided, and announced the subject of the evening to be "Snow Removal."

Mr. Hudson gave a comprehensive résumé of the extraordinary snow conditions in Chicago during the past winter.

Papers were presented reporting the manner in which the snow was removed by the various park boards and the city authorities, as follows:

Mr. George T. Donoghue, Engineer of the Lincoln Park Board, Mr. W. J. Galligan of the Bureau of Streets, Mr. Harry Richards, Superintendent of the South Park Board, and Mr. A. C. Schrader, Engineer, West Side Board.

The paper was discussed by Messrs. Roper, Stephenson and Lowell.

These addresses were illustrated by numerous slides showing the condition of the city streets and also slides showing the snow conditions on the various railroads entering Chicago.

MEETING NO. 998, MONDAY, MARCH 11, 1918.

This was a meeting of the Bridge and Structural Engineering Section. There were present fifty members and guests of the Society. Mr. J. W. Lowell, Jr., Chairman, presided. The subject of the evening was "Principles of Design and Construction of New State Penitentiary at Lockport, Illinois." Mr. Albert Moore Saxe, Architect of the firm of Zimmerman, Saxe & Zimmerman, described the construction features and the design of this penitentiary, which represents the latest advance in the housing of prisoners. The paper was illustrated with slides.

The Secretary reported that at the meeting of the Board of Direction of March 11th, application for membership were received from the following:

L. G. Leopold Thomas, (Transfer from Student)..................Chicago
George T. Jennings, (Transfer from Junior).......................Chicago
Arthur L. Evans...Chicago
John W. Lowell, Jr., (Transfer from Associate)...................Chicago
Maxwell C. Tobias...Chicago
Albert A. Colvin..Wheaton, Ill.
Howard A. Carter..Chicago
Louis R. Howson...Chicago
Whitfield E. Lewis..Des Moines, Ia.

The Secretary also reported that the following had been elected to membership in the Society:

Robert O. Scholz, Jr., Chicago..............................Junior Member
Porter R. West, Chicago (Transfer from Junior).................. Member
Roger Bradshaw Quincy, Chicago..............................Junior Member
Fred Weber, Chicago...Junior Member
John C. McNicol, Lemont, Ill.................................... Member
Jack A. Scanlon, Chicago.................................Associate Member
Eugene T. Morrison, Chicago..................................... Member
Frank T. Danielson, Evanston, Ill..........................Student Member
Emory H. Huston, Evanston, Ill.............................Student Member
Walter E. Cowan, Chicago....................................Junior Member
John A. Sauerman, Chicago (Transfer from Junior)................ Member
Karl M. MacDuffee, Des Moines, Ia..........................Student Member
George Harold Jennings, Joliet, Ill............................. Member
Earl H. Buchanan, Pasadena, Cal., (Transfer from Student)..Junior Member
Karl Udet, Marion, Iowa.....................................Junior Member

Charles E. Stickney, Marion, Iowa........................Junior Member
Mark H. Place, Chicago.................................... Member

MEETING NO. 999, TUESDAY, MARCH 19, 1918.

This was a general meeting of the Society, there being present 108 members and guests. To this meeting there has been invited the delegates attending the annual meting of the American Railway Engineering Association. Mr. James N. Hatch, First Vice-President, presided. The subject of the evening was "Meeting the Material Situation." Papers were presented on various phases of the subject as follows:

"The Material Situation as Viewed by the Steel Industries," Mr. F. J. Llewellyn.

"The Material Situation as Viewed by the Lumber Industries," Dr. Hermann Von Schrenk.

"The Material Situation from the Standpoint of the Cement Industries," Mr. B. F. Affleck.

Mr. Frank Rhea of the United States Department of Commerce and Labor, presented the impressions he had gained during a seven months' study of labor conditions in Japan, Corea, China and Manchuria.

Mr. Edward Gray, Valuation Engineer of the Chesapeake and Ohio Railroad Company, gave a résumé of the distribution of labor in the United States under existing war conditions.

A moving picture showing the launching of the 5,000 ton concrete ship "Faith" was given.

MEETING NO. 1,000, MONDAY, MARCH 25, 1918.

This was a joint meeting of the Electrical Engineering Section, W. S. E., and the Chicago Section, A. I. E. E. Mr. C. A. Keller, Secretary of the Chicago Section, A. I. E. E., presided. There were present 125 members and guests. Mr. Charles F. Burgess presented a paper on the subject of "Some Possibilities in the Electro-Chemical Industries," which was followed by discussion by Messrs. Hoskins, Jewell, Willard, McCoy, McClure, Lowell, Autey, Shnable and Harbaugh.

EDGAR S. NETHERCUT,
Secretary.

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BOOK REVIEWS

The Gas Engine. By Max Kushlan. 366 pages 5 by 8 inches, profusely illustrated, bound in cloth. Published by The Branch Publishing Company, Chicago. Price, $2.50.

Gas and gasoline engines or motors, or more properly perhaps, internal combustion engines, have a great variety of forms for various purposes. From the detachable row-boat motor or "kicker" to the Diesel engine of the submersible or large motor ship, including all the forms of automobile and aeroplane power plants, the principles of internal combustion are utilized. While the engines vary somewhat depending on their purpose, fuel, etc., this book covers the general principles of the different styles of engines, describing the necessary parts, without much attempt at the refinements which would take one into technical discussions. The beginner will appreciate the plain descriptions and the pertinent illustrations, while the experienced operating engineer can profitably read the little volume.

Among the subjects treated are Elementary Theory of Internal Combustion Engines, Gas Supply, Elements of Single and Multiple Cylinder Engines, Ignition, Lubrication, Cooling, Automobile Motor Transmission and Operation, Motor Requirements for Aviation and Types of Aviation Motors.

Many excellent suggestions are made regarding the different types of engines for the different purposes, the descriptions applying to the design as well as to the operation. C. A. M.

The Chemical Analysis of Iron. By Andrew Alexander Blair. Eighth Edition. 318 pages 6 by 9 inches, with over a hundred illustrations, drawings, etc. Bound in Cloth and published by J. B. Lippincott Company, Philadelphia. Price, $5.00.

Iron and steel have been greatly developed along both mechanical and chemical lines during the past thirty years. The methods formerly used have been improved and the necessity for accurate determinations of the physical and chemical properties has made a book like this not only convenient, but most necessary. Combining as it does in one volume the various approved methods for the analysis of iron, steel, pig iron, alloy metals, iron ore, limestone, slag, clay, sand, coal and coke, as used in the iron and steel industry, as well as descriptions of special apparatus to facilitate the analytical work, it will be of value to the chemist as well as to those wishing to make a comprehensive study of the ores, metals, etc., found or used in connection with iron and steel manufacture.

Many of the formulas and processes have been in general use for years, although the long experience of the author is drawn upon for the practical instructions for conducting the tests, analyses, etc. Practical methods are given the preference, as the author realizes that the book will be used largely as a workers' manual.

Having passed through seven editions, the present volume represents not only the author's own views, but the suggestions for improvement and expansion from the many who have followed the preceding editions. A remarkable clearness and conciseness marks every process, and it would seem that no one interested in the laboratory study of iron should be without this edition. C. A. M.

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HOW AMERICAN INDUSTRY CAN MEET WORLD COMPETITION AFTER THE WAR

By William O. Lichtner, M. W. S. E.*

Presented April 1, 1918

PREFACE

At the instant that the war comes to an end, there will be a tightening up and quickening of world industry in order to make up the losses of the war. America will be called upon to face this quickened world competition and to face it triumphantly. The object in writing a paper at this time is an attempt to arouse American manufacturers to a realization that, if they expect to be prepared to meet this world competition after the war, they must take immediate action. American industry is not prepared to meet it today.

AMERICA'S FAILURE

For a hundred years Americans have been boasting that the American executive is not a thinker but a doer. This boasted fact is the root of a great evil,—the cause of expensive waste of energy and materials. Our executives are to an alarming extent at the mercy of their subordinates for, not knowing the details of their own business, as well as their subordinates, they do not know how to improve their methods. Vague thinking, too, on the part of the manager inevitably results in inefficient workers.

These lax methods and this waste of man power through stress on doing, without the inevitable preliminary planning, have been possible in the past; but they will not be possible in the future. Labor, both mental and physical, is bound to become dearer and scarcer every day. The characteristic American "hustling," the ever intense effort, the too strenuous application, must now give place to scientific economy of materials and energy.

Nevertheless, superintendents are still managing as they have always manager. I know it is a fact, that there is no shop of any size, which does not employ a large number of men unfitted for the particular piece of work which they are supposed to do. The results are evident in labor conditions today: discontented workmen, poor work, and high costs. There is still fearful dissipation of time and materials, of human strength and thought.

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The Honorable Wm. C. Redfield in his book on "The New Industrial Day" calls upon the nation to wake up to the fact that we are living in a new era of revolution instead of in one of the past where "rule-of-thumb" methods applied. He writes

> "The day of rough and ready contests as with the bludgeon and the fist has gone in our industrial fight, and we must use keener and more accurate weapons and carry on the contest at longer range and with more trained antagonists than these with whom until recently we have had to deal."

One cause of the continuance of the old, outgrown conditions is the mushroom-like growth of American industries. The small manufacturers' time and cost system is very simple, requiring only a few clerks to figure the pay-roll and the cost of the jobs. As the business grows a few more clerks are added from time to time until suddenly the management find that they have a tremendous clerical force handling the cost system with a hundred or more forms to fill out, the majority of which are practically worthless after one item is taken off of them. The fact is that many of these large concerns have grown so fast that they have not had the time to give thought as to whether or not the records they were keeping were of any value. The management has not had the time to follow up the developments each day, but has depended more and more upon the men below them. If we go into some of the large establishments of today and ask the Works Manager to write out a detailed description of every step through which some standard product must pass, we find in 99% of the cases he is unable to do so without first consulting his superintendent, then his assistant superintendent, then the foreman and finally the workman himself. Is this a safe basis upon which to establish any business?

The cure is so simple and experience has proved it so unfailing that it is indicative of the slovenly thinking on the part of the American Manager that it has been followed only in a small number of cases. Wherever tried, the following suggestions have been invariably successful:

1. Make a written analysis of the best way of doing each piece of work, taking into account the prejudices, superstitions, and opinions of the workmen. Weigh each element of these ideas in relation to each other and themselves and out of the maze of information develop tentative standards until detail studies can be made on each point and scientifically developed.
2. Train competent instructors to teach the workers how to use the information most effectively.
3. Pay efficient workers a high wage which a competent man will feel worth striving for, and, conversely, pay the inefficient worker a low wage commensurate with his inefficiency.

The man whose business has grown up over night and who finds his system inadequate to this sudden growth, and the executive who believes his success is due to his particular organization, methods and equipment, and will not listen to any "new fangled notions" might well give heed to some pointed statements made by Mr. Redfield before the Business Men's Club in Cincinnati.

> "A thing is not right because we do it,
> A method is not good because we use it.
> Equipment is not the best because we own it.
> The best of us have much to learn,
> None of us can afford to be deceived about our own affairs.
> It is better by self catechism to find and correct our own faults than to have our customers do it for us."

GERMANY'S SUCCESS

If we are ready to acknowledge that we have much to learn, we may as well acknowledge that we can learn something from Germany's military success in past wars. It was due to her preparation for war in times of peace, when she could analyze and standardize everything, that the entire machinery worked perfectly when the crisis came. Every branch of the administration was kept constantly informed of the exact military and political situation. The orders for marching were worked out for each division of the army, even to the starting point, the hours of departure, the refreshment stations, the length of the journey and the destination. When war was declared, it required, according to Von Moltke, only "the royal signature," in order to carry out the plans elaborately prearranged. This vast and detailed scheme manifestly calls for a superior class of executives of all ranks, adequately prepared for their duties.

To provide such officers, Germany has perfected her war power and General Staff with every educational and scientific agency which human ingenuity can devise. To these institutions the flower of the regimental officers is drawn for training. From these institutions they soon return to the regiments. In this way a constant transfusion of talent is taking place between the regimental lines and the General Staff, and there is insured to the Commander-in-Chief a body of capable officers familiar with each element of service and trained to intelligent coordination of efforts. The results, not only in previous wars, but in the initial surprises of this war which have given her such immense strategic advantages, have proved the marvel of the world.

What Germany has done in the organization of war can be done in the organization of peace. Not only the general plans but each last detail could be so arranged by trained executives that an industrial process should have something of the unimpeded resistless character of a German mobilization. It is only too apparent in

our work today that by putting accent on doing and not on thinking there is a terrific waste of man power, namely, of skill, faith, and experience. When shall America show that the great affairs of a country's industry can be administered with the same perfection as this business of destruction and bloodshed?

THE POSSIBILITIES UNDER SCIENTIFIC MANAGEMENT METHODS

The immense losses which have been permitted through the "rule of thumb" methods and the immense gains that may be made through the establishment of the new Scientific Methods are no longer mere matters of theory. In 1910, when the Interstate Commerce Commission instituted an inquiry into the reasonableness of the proposed advance in freight tariff, the world was startled by the statements that the railroads of the United States might save $1,000,000 a day by paying greater attention to efficiency of operation. Since then we have been finding similar leakages throughout the business and industrial world. Although in the municipal government work of our large cities the greatest loss has been through direct graft, the report of the New York Bureau of Municipal Research shows that millions of dollars were being wasted in our largest city because a few efficiency principles were not observed in the buying of the city's supplies in the conduct of department. The discovery of leakages has in some cases—although in too few—resulted in their stoppage. At the Frankford Arsenal $250,000 has been saved in the manufacture of ammunitions, along with an additional indirect saving of a million and a half dollars for the year. Dr. Hollis Godfrey gives an eloquent example of the savings possible under scientific methods in a sworn statement before the "House Committee to Investigate the Taylor and other systems of Management." *H. Res. 90- Vol. 3, Page 1846.*

> "The first plant under scientific management with which I was connected with was the Tabor Manufacturing Company. I had full opportunity there to see all books and figures, and nothing was more impressive to me than the fact that the Tabor Company, with approximately the same number of men and machines as were used under the old system, was turning out three times the production; that it was giving 75 percent higher wages to the workmen; that it had made a 25 percent reduction in the selling price of machines, thereby producing so much saving to the consumer. Moreover, that this Company, which has lost money before the introduction of Scientific Management were now and had been making a profit; that from the condition of a strike and inharmonious relations before the introduction of scientific management there had come about the friendliest feeling between management. workmen and outsiders."

DETAILED ACCOMPLISHMENTS UNDER SCIENTIFIC MANAGEMENT

A few more specific accomplishments personally known to the writer are noteworthy. The class of work in these cases will be illustrated and the results cited.

1. *Making Paper.*

The paper which we use as letterheads and writing paper is in a continuous roll, the width of the roll being about ten feet and the length depending upon the thickness of the sheet of paper. Increase of production of a paper machine can be accomplished in three ways: (1) by increasing the speed of the machine, (2) by widening the sheet on the paper machine, or, as it is technically known, increasing the deckle width, and (3) by reducing the number and length of shutdowns through better planning of the orders.

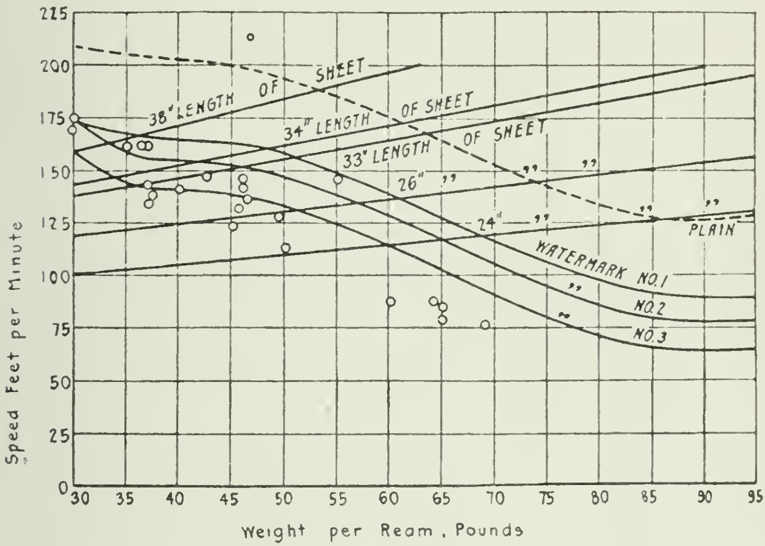


Fig. 1. Speeds of Paper Machine for a Certain Grade.

To establish correct speed standards, past records were tabulated showing the speed of the paper machine for each kind of paper run on the machines. It was found that with the same furnish the speeds of the machine at different times would vary as much as 50 per cent. This variation in speed was caused sometimes by variation in the condition of the stock, and particularly by the lack of uniformity.

As a result of this study and through the partial standardization of beating, definite speeds for certain grades of paper were established for each furnish, and were specified to the men on the

machines with each order. In Fig. 1 are shown the curves for one kind of paper for different weights of stock and different watermarks. For uncut paper the standard speeds are indicated by the curved lines. If the paper is cut at the end of the machine into sizes indicated by the straight lines, the speed is limited by the length of sheet cut off as well as by the weight. Then the speeds for plain paper cut into sheets 34 in. in length would follow the dotted curves until they reach the straight line marked 34-in. and then follow this straight line. For example, 50-lb. plain paper of this grade would be run at a speed of 195 ft. and 70-lb. paper at 180 ft. Before fixing these standards there was no definite relation between speeds for different weights. It was found possible to increase the speed as much as 30 per cent—and sometimes more—over the average of the old speeds. The small circles on the diagram show the variable speeds before standardization.

Another big factor in the saving of dollars and cents was the forming of a sheet of paper off the end of the machine which would not be appreciably overweight. Paper is bought on the specification, for instance, that 500 sheets of 24-in. x 36-in. should weigh 80 lb. This assumes, however, that the weight can vary 2½ per cent either way of the 80 lb. Therefore, any sheet taken off the machine which will give just a weight of 80 lb. for 500 sheets will bring just as much money as a sheet 2½ per cent over weight, or 82 lb. If the sheet, on the other hand, is more than 2½ per cent underweight, the paper is sold by actual weight. The uniformity in weight also makes it more acceptable to the customer. Besides this, the paper has certain qualifications in the color of the sheet, the rattle, tear, etc., all of which can be affected by the machine man.

By studying conditions and standardization it was found possible to obtain more uniform and normal weights. To maintain these characteristics of weights and quality at a high standard, a bonus was outlined for paying the machine tender and his assistant according to the saving which they made on these various factors. In Fig 2 is shown the actual record of variation from the limits specified to the machine tender and the bonuses earned. Formerely, the majority of paper had been run overweight and with large variations. In the example shown, the bonus earned is 95 per cent of the maximum, or $3.60. In addition to this bonus is another of $3.00 per week maximum, based on production.

Further increase in the output of the machines was found practical from time to time by increasing the deckle width. The number and length of shutdowns of the paper machines have been reduced through more planning of the runs to avoid changes. As a result of these studies, there has been an increase in output and in wages, and a great decrease in cost.

2. Squaring Paper on Power Cutter.

Writing paper is cut from the paper in rolls into sheets 22½ in. by 34¾ in. Thousands of these sheets are then put into a so-called "power cutter," known as a guillotine or straight-edge cutter (see Fig. 3) for trimming the sides of the paper, making it 22 in. by 34 in. and perfectly square all around. The operation is done as follows:

A certain amount of paper is placed on the bed plate of the machine and jogged up to the back gage. One edge is trimmed, the paper is then turned 180 deg., the gage is set, the second edge trimmed, and so on until four edges are trimmed.

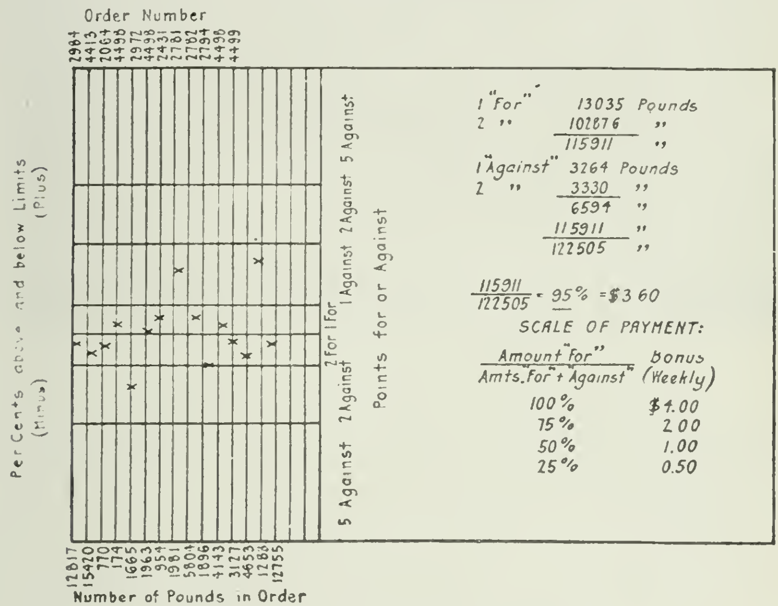


Fig. 2. Weight Bonuses on Paper Machines.

It is apparent that one great factor in the economy of this operation is the amount of paper that can be trimmed with one cut of the knife. A scientific study was made of just how much of each of the different kinds of paper could be cut at once without damaging the stock, and the thickness of the knifeful prescribed for each. The proper sequence in which the different edges should be trimmed in order to expend the minimum of time and effort was also determined. The amount of paper a man could lift from the truck to the trimming table and from the trimming table back to another truck without strain or undue fatigue on him, or danger of cracking the surface of the stock, was also determined. The

curve indicating the amount of paper per lift is shown in Fig. 4. The small amount below the 35-lb. weight is due to the lightness of the paper.

Fig. 3. Trimming Paper.

When the results were finally obtained, it was found that the amounts that could be accurately cut varied with different kinds and weights of stock from less than 3 in. to about 5½ in., the maximum that could be placed in the machine.

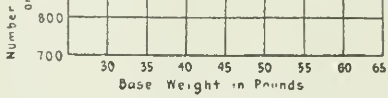


Fig. 4. Number of Sheets Per Lift for Trimming.

The following results were obtained:

A. Increase in output...............47%
B. Increase in wages...............33%
C. Decrease in cost.................26%

At another plant where the operation was similar to the above, except that the size of the paper was 40 in. by 60 in., which necessitated the operator having an assistant to help lift the sheets on and off the machine as well as to turn them on the bed of the machine.

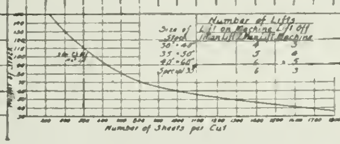
LITHO STOCK 22" × 28"

	Place Stock on Machine per Lift			Trim Stock 2 Sides & 1 End per 3 Trims					Trim Stock 1 Side & 1 End per 2 Trims						Remove Stock from Machine per Lift		Miscellaneous per Truckload		Change Jobs per Job
	1 Man Lift	2 Man Lift	35°	a	1st	2nd	3rd	a	35°	a	1st	2nd	3rd	a	2 Man Lift	35°	Stock Flat	Stock [illegible]	c
Net Time + 35%	0.23	0.40	0.82	0.11	2.52	2.89	3.28	0.15	1.87	0.11	1.81	2.01	2.22	0.13	0.50	0.81	3.48	4.50	4.91
Net Time	0.17	0.30	0.61	0.08	1.87	2.14	2.43	0.10	1.39	0.08	1.34	1.49	1.65	0.10	0.37	0.60	2.58	3.34	3.64
Walk from Machine to Truck	0.03	0.03	0.03																
Get Stock in Hand	0.10	0.09	0.14																
Carry Stock to Machine	0.04	0.04	0.04																
Jog Stock to Gage		0.06	0.25	0.03						0.03									
Hit Sides & Front with Stick		0.08	0.17	0.05						0.05									
Run Gage Back for 1st Trim " " " " 2nd " " " " " 3rd "					0.16 0.10 0.06	0.16 0.12 0.06	0.16 0.13 0.05		0.16 0.05		0.16 0.04	0.16 0.04	0.16 0.05						
Push Stock to Gage					0.07	0.10	0.12		0.10		0.07	0.10	0.12						
Set Gage by Hand {2 Times 3 "					0.12	0.12	0.12		0.12		0.12	0.12	0.12						
Place Pad Under Edge								0.10						0.10					
Trim Stock - 1st Time " " - 2nd " " " - 3rd "					0.05 0.08 0.05	0.05 0.08 0.08	0.05 0.08 0.08		0.05 0.08		0.08 0.08	0.08 0.08	0.08 0.08						
Throw Waste in Box"					0.01	0.01	0.02		0.02		0.01	0.01	0.02						
Turn Stock for Next Trim					0.17	0.27	0.48		0.26		0.17	0.27	0.40						
Run Up Gage for 2nd Trim " " " " 3rd "					0.06 0.10	0.06 0.12	0.05 0.13		0.19		0.10	0.12	0.13						
Run Up Gage for Removing Stock					0.16	0.16	0.16		0.16		0.16	0.16	0.16						
Get Stock in Hand															0.14	0.24			
Carry Stock to Truck															0.04	0.06			
Even Stock on Truck															0.13	0.26			
Walk from Truck to Machine															0.03	0.03			
Hit Sides & Ends of Stock															0.05	0.05			
Set Machine for Next Lot					0.21	0.21	0.21		0.21		0.21	0.21	0.21						
Remove Cover Boards (4 per Truck) Place " " (4 " ")																	0.08 0.31	0.08 0.58	
Mark Trimmed Stock																	0.68	0.68	
Change Truck Card																	0.66	0.66	
Change Instruction Card																			3.64

1st Letter
p = Place Stock on Machine
t = Trim "
r = Remove Stock from Machine
m = Miscellaneous Items
c = Change Jobs
a = Add This Item

2nd Letter
o = One Man Lift
t = Two " "
s = Special Case
n = Narrow Stock
m = Medium Width Stock
w = Wide Stock
u = Uneven Stock

3rd Letter
t = Two Sides Trimmed
o = One Side Trimmed



* 60 Pound Stock or Under When Trimmed for Litho Printing is a 1 Man Lift Except When Trimmed 2 Sides & 1 End, Then it is a 2 Man Lift
† This is One to Last Lift
‡ Multiply by 2
" " 3
‡‡ This Operation Takes Place While Gage is Running Back
|| Helper Removes Board While Machine is Being Set.

TABLE 1. RATE CHART FOR TRIMMING LITHO PAPER

The results obtained in the case were even more gratifying, for the company was saved from doubling the number of machines they had and from making an addition to their building. The results were as follows:

A. Increase in output........................125%
B. Increase in wages........................ 50%
C. Decrease in cost........................ 48%
D. Cost of work done on flat time decreased.. 26%

3. Cutting Large Size Paper Into Small Sections.

One of the most difficult analyses the writer has made was on the operation of cutting large sheets of paper 40 in. by 60 in. into small rectangular pieces of varying sizes. The weight of the sheets varied from 30 pounds to 250 pounds per ream of 500 sheets.

This class of work requires the greatest skill, as the operator must be able to cut to a hair line. The stock also is very expensive

due to its having been lithographed or printed with a number of different color combinations. The master sheet showing just how the cutter is to cut the stock, is made up by the foreman before the work is assigned to the machine. Formerly, each operator made up his own master sheet, which took anywhere from half an hour to eight hours, depending upon the complexity of the lay-out on the sheet or the number of change orders attached to the instruction. While this was being done, the machine remained idle. The operations of cutting the stock into sections are shown in Fig. 5.

Fig. 5. Cutting Paper Into Small Sections.

The results obtained were as follows:

A. Increase in output...............69%
B. Increase in wages...............33%
C. Decrease in cost................34%

Fig. 6 shows the layout of the room before and after the work was systematized. The reduction in number of machines from 11 to 8 made the rearrangement of the room possible, so that at least one job could be provided ahead of each machine and also storage space allowed for work coming into the department and for the finished work awaiting the electric truck to remove it to the next department.

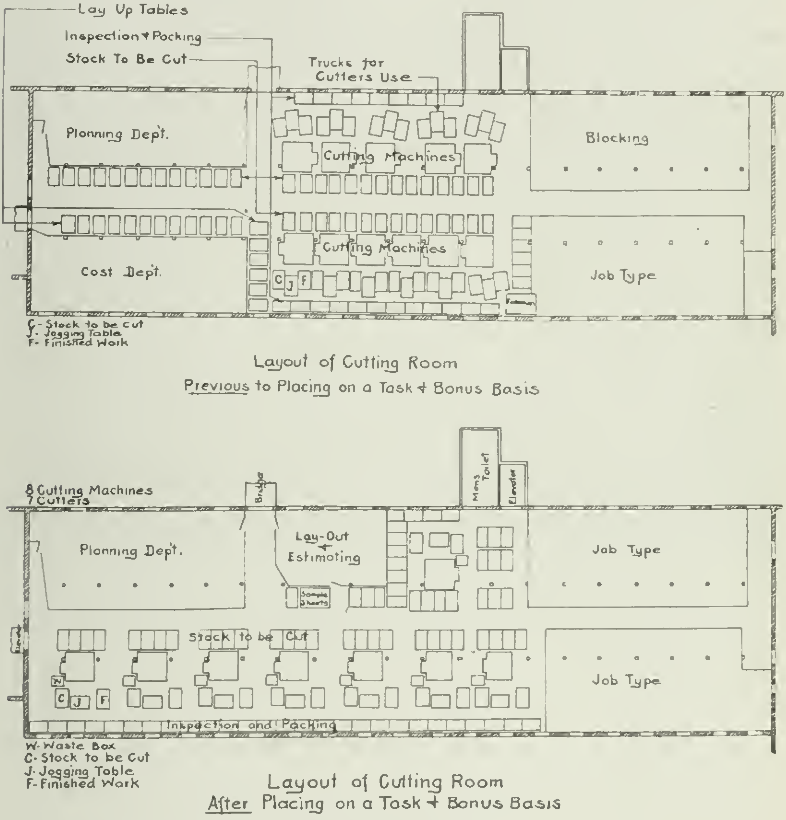


Fig. 6. Layout of Cutting Machines Before and After Task Work Was Established.

4. *Sorting Coated and Glazed Paper.*

The operation of sorting coated and glazed paper is an important inspection operation which requires quickness of perception and quick judgment to decide almost instantaneously whether a sheet is all good, all bad, or partly good. In some cases the operator must have a very keen sense for differentiating between slight differences in shades of color.

Fig. 7 shows the original layout of the room with some of the operators facing the light, while others have their backs to the light.

Fig. 7. Old Layout of Sorting Department.

Fig. 8 shows the same department with the light falling on the work of all operators from the side. This change not only improves the judgment of the worker, but has had another very desirable effect, in that the work can be taken to and from the operatives very much more expeditiously and the available floor space can be utilized to better advantage.

The results accomplished in this department have been as follows:

A. Increase in output..............150%
B. Increase in wages.............. 32%
C. Decrease in cost............... 39%

5. *Die Cutting Labels.*

Labels used on cans, bottles and boxes and packages of all kinds are printed or lithographed on large sheets of paper so as to get as many as possible on one sheet. They are then cut out of the sheet with a cutter called a die. The shape of the label may be square, round, oval, or have a very irregular edge. A number of

large sheets, 15 to 50, are wired or pinned, so that by accurately placing the die over one label at a time on the top sheet, the die when hit with the mallet will cut the other labels accurately. At one plant the die cutting of small labels is done by girls as shown in Fig. 9.

Fig. 8. New Layout of Sorting Department.

This work is fairly heavy work for women operators, as it must be done with a mallet weighing several pounds and necessitates the operator standing or partially reclining against a stool or stand. A number of experiments were made to determine the proper platform to use and the pitch and height of the cutting block; and a slotted spring platform raised about one or two inches from the floor was found to absorb considerable of the jar occuring to the operator with each stroke of the mallet.

The saving to the company by putting this work on a task basis amounted to about 40%, and it gave the operators an average increase in pay of 43½%.

At another plant the die cutting is done on a "Clicking" machine, which supplies the power for driving the die through the

paper. A tray, shown in Fig. 10, in which to place the labels after cutting was also devised, which alone saved the operator 5% of time. The study also showed that by having small lines printed at each corner of the labels one millimeter from the cutting line, it was possible to place the die by sighting from the outside of the die instead of clearing the die each time a cut was made and sighting from the inside. This change in method alone increased the production 20%.

Fig. 9. Die Cutting Labels by Hand.

The results were as follows:

A. Increase in output varies with class and character of work. Saving equals from 50% to 160%

B. Increase in wages........................35%

C. Decrease in cost.........................73%

6. Inspection of Die Cut Labels.

The labels after being die cut are taken in racks to the Inspection Department, where they are inspected and strung ready for packing and shipping.

There is an erroneous idea prevalent in a number of manufacturing establishments that to put inspection work on to a bonus or piece rate means "poor" work. This is true if the inspection system which is installed is not properly worked out. Any inspection which is done by inexperienced help with little or no supervision, as it is in the average shop, is practically worthless even if

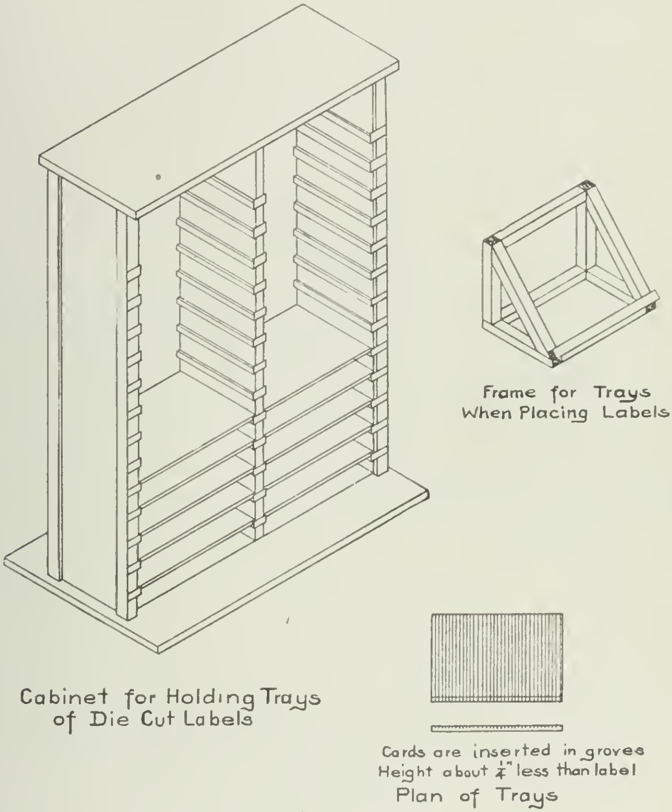


Fig. 10. Tray for Holding Small Die Cutting Labels.

the operators are paid straight day wages. In this case where the Inspection System was worked out with scientific care, the results obtained by putting the inspection of die cut labels on task work were as follows:

A. Increase in production varied from 70% to 188%
B. Increase in wages........................50%
C. Decrease in cost..........................24%

7. Sulphite Pulp Manufacture.

A graphical illustration (see Fig. 11) shows how in some industries it is possible by a scientific study to decrease materially the quantity of material used in manufacturing, and at the same time get a large increase in output.

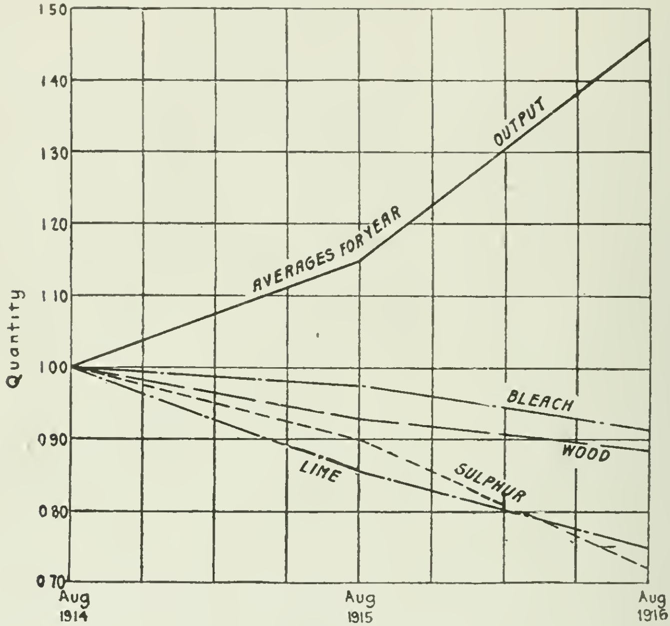


Fig. 11. Ratios Showing Decrease in Materials and Increase in Output.

Fig. 12 shows the difference in the uniformity and density of pulp before and after the density tests were made regularly, and a bonus paid to the men upon keeping the density within specified limits.

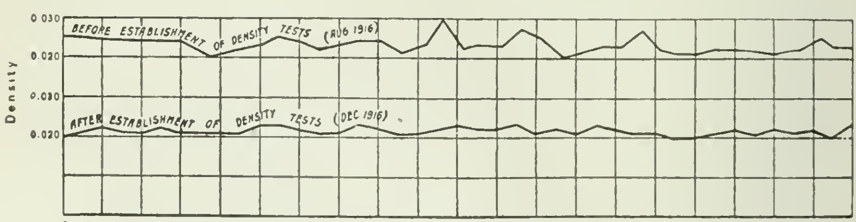


Fig. 12. Density of Pulp Before and After the Establishment of Density Tests.

8. Spinning in Textile Mill.

The output of the spinning frames of a textile mill is dependent to a large degree on the so-called Doffing Crew who doff the machine, i. e., take off the full bobbins and place empty bobbins ready to fill. The average number of spindles to a side is about 60, and these have to be changed all at one time, which is accomplished by using a crew of 8 girls or boys who handle everywhere from 6 to 10 spindles each, according to their ability.

The increase in production of the spinning frames in one mill was accomplished solely through regulating the exact running time of the machine to get maximum yarn on the bobbins and by doffing

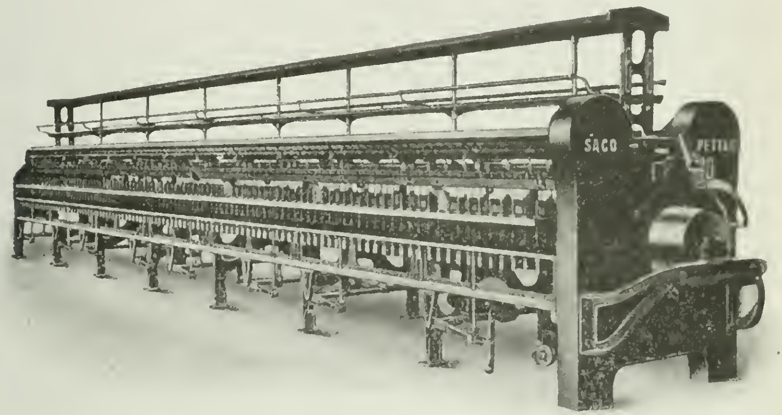


Fig. 13. Spinning Frame.

the machine in the shortest time possible. The results which were accomplished by this means alone were as follows:

A. Increased output of Spinning frame 4% by putting Doffing Squad on a Task basis.
B. Eliminated 1 Doffing Squad out of 7.
C. Increased pay of Doffing Squad 13%.
D. Decreased cost of doffing 6½%.
E. Saving to company in one mill, about $4,500, or $20,000 when applied to all mills.
F. Quantity and uniformity of yarn in bobbins greatly improved.

9. Coating Metal.

Metal is coated with paint or varnish by running the sheets of metal between rolls, one roll of which revolves in a trough of paint or varnish. The sheets are caught on moving tapes which convey them to the racker for racking ready to be placed in the ovens for drying. This machine is shown in Fig. 14.

The results obtained by putting the process on a task and bonus system were as follows:

A. Increase in output......................75%
B. Increase in wages......................25%
C. Decrease in cost.........................40%

Fig. 14. Coating Metal.

10. Laying Gold Leaf.

The gold letters on the covers of books are made by laying a very thin sheet of gold leaf on the cover as shown in Fig. 15 and then stamping with a hot die which leaves the gold letters firmly imprinted on the cover, while the other loose gold leaf is wiped off with a composition sponge from which the gold is reclaimed. Fig. 15 shows the book cover after it has been die stamped and the excess gold is brushed off.

This is an operation where the saving in material is of first importance. The amount of saving is dependent upon the skill of the operator in handling the gold leaf without loss as well as being able to accurately place the leaf in position. The bonus was, therefore, based on the three conditions, namely:

A. Saving Gold Leaf.
B. Accuracy.
C. Speed.

Fig. 15. Gold Leaf on Book Cover Before Die Stamping.

The bonus for speed is not allowed unless both the "saving" bonus and the "accuracy" bonus are made, and the "accuracy" bonus is not allowed unless the "saving" bonus is earned; so that the saving the worker himself effects through his deftness is made the condition of his reward.

Fig. 16. Finished Book Cover After Die Stamping.

11. Laying Cloth.

Men's and women's garments and coats when manufactured in large quantities are cut in batches of 20 to 50 at one cutting by laying up the cloth in layers. Two sizes of garments are cut from one length of cloth, which makes less waste than if only one size is cut out of a length. The operation of laying the cloth up properly would seem like a very simple operation on which to make a scientific

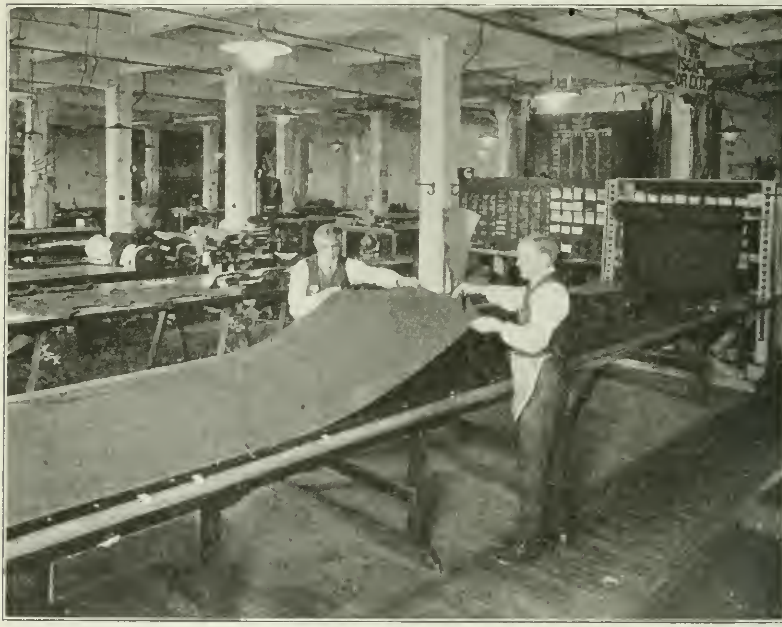


Fig. 17. Laying Cloth.

study. The different kinds of texture, however, necessitate different ways of handling the cloth so as to prevent the layers from shrinking after being laid or the pattern from becoming crooked. It is impossible also to purchase perfect cloth so that a skillful layer can reajust his pattern to use a trifle more cloth in some one or two layers so as to avoid the bad spot or mark the cloth or throw it into a small part or a part where a slight blemish will pass. The result accomplished by putting the laying on task work were as follows:

A. Increase in production..................15%
B. Increase in wages.......................25%
C. Decrease in cost........................ 0%

12. Cutting Cloth.

After the cloth is properly laid up a paper marker is laid on top of the lay and pinned to the cloth. This paper lay has previously

been perforated showing the exact sizes and shape of each part of the die, so that an operator can cut out the parts with an electrically operated knife as shown in Fig. 18. The results accomplished are as follows:

A. Increase in production..................40%
B. Increase in wages.......................25%
C. Decrease in cost........................28%

Fig. 18. Cutting Cloth with Electrically Operated Knife.

13. Laying and Spraying Buttons.

The buttons used on clothing are made from the vegetable ivory nuts, technically known as *Phytelephas Macrocarpa,* which grow in Panama at Temaco, Esmeralda and Manta in South America.

Fig. 19 shows the original ivory nut and the various stages through which it passes in the manufacture of the buttons.

The nuts are first sawed into slabs or sections by means of a fine-toothed circular saw. The nut is so sawed as to get off the maximum number of large size slabs in order to get as large buttons as possible. The small sizes, although used in large quantities, are readily produced, as they can be turned out of large stock if neces-

sary, but this condition practically never arises. The slabs or sections are then placed in a lathe and the button turned.

The next operation is to dye the buttons, which are white, by either immersing them in a dye bath, after which they are developed if they are all to be one color, or, if they are to be mottled, by placing them on pins on a board so that a chart can be placed over them

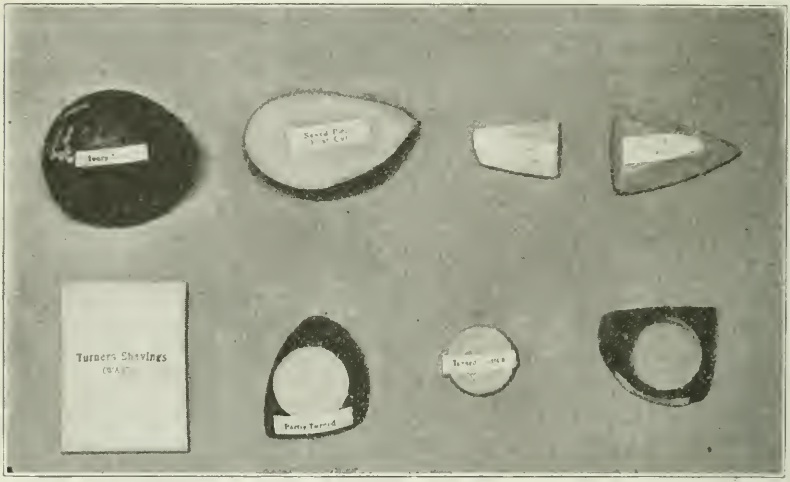


Fig. 19. Evolution of a Button from the Ivory Nut.

through which the dye is sprayed. After spraying, the buttons are removed from the board and developed like a photographic plate.

The operation of laying and spraying buttons is shown in Fig. 20.

The results accomplished in this work were:

A. Reduction of the number of classes of different kinds of sawed stock from some 37,550 down to 828.

B. Replacing the men sawyers by girls, which was made practicable by introducing mechanical safety devices to prevent accidents to the operatives' hands.

C. Increase of output of the turning lathes by a study of the stock questions and the best type of turning tools and proper method of honing them.

D. Breaking up of the gang work of laying and spraying, which increased output 75% per operator. This was accomplished by constructing a very simple arrangement which acted as a humidifier. As each board was filled with buttons, a galvanized iron cover with a wet pad in top was placed over the buttons, which kept them at an even degree of moisture. In this way the girls could be assigned the work of laying independent of the spraying.

PRESENT DAY RESPONSIBILITY OF THE MANAGEMENT

The results which we have just seen are significant as steps toward the accomplishment of the principal object of all management; that is, to secure the *maximum* prosperity of the employer coupled with the *maximum* prosperity of each employe.

There are no easy ways by which this "maximum prosperity" may be achieved. It is impossible to get up a standard set of forms and write up a standard set of instructions which can be used by any manufacturer. There must be a special scientific study of the details of each special sort of work, but, most of all, the management must now take upon itself the fullest responsibility.

Fig. 20. Laying and Spraying Buttons.

Under the old type of management, success depends almost entirely upon getting the "initiative" of the workman, and it is indeed a rare case in which this initiative is attained. Under the new type of management the initiative of the workman, that is, his hard work, good will and ingenuity, is obtained with absolute uniformity and to a greater extent than is possible under the old system; and the reason for this improvement on the part of the men is that the managers assume new burdens, new duties and responsibilities, never dreamed of in the past.

It is the combination of the initiative of the workmen, coupled with the types of work done by the management, that makes the

new management so much more efficient than the old. The managers assume, for instance, the burden of gathering together all the traditional knowledge which in the past has been possessed by the workmen, and then the task of classifying, tabulating and reducing this knowledge to rules, laws, formulas, which are immensely helpful in doing their daily work. In addition to developing a science in this way, the management takes on three other types of duties which involves them in new and arduous labors. These are grouped under four heads:

1. They develop a science for each element of man's work as explained above, which replaces the old rule-of-thumb methods.
2. They scientifically select and then train, teach and develop the workman where in the past he chose his own work and trained himself as best he could.
3. They heartily co-operate with the men as to insure all of the work being done in accordance with the principles of the science which has been developed.
4. There is an almost equal division of the work and the responsibility between the management and the workmen.
5. The management take over all work for which they are better fitted than the workmen, while in the past almost all the work and the greater part of the responsibility were thrown upon the men.

The fourth of these elements, "an almost equal division of the responsibility between the management and the workmen," requires further explanation. The philosophy of the usual management of "initiative and incentive" has made it necessary for each workman to bear almost the entire responsibility for the general plan as well as for each detail of his work and in many cases for his implements as well. In addition to this he must do all of the actual physical labor. The development of a science, on the other hand, involves the establishment of many rules, laws and formulas which replace the judgment of the individual workman and which can only be effectively used after having been systematically recorded, indexed, etc. The practical use of scientific data also calls for a room in which to keep the books, records, etc., and a desk for the planner to work at.

Thus all of the planning which under the old system was done by the workman, as a result of his personal experience, must of necessity under the new system be done by the management in accordance with the laws of science, because even if the workman was well suited to the development and use of scientific data, it would be physically impossible for him to work at his machine and at a desk at the same time. It is clear also that in most cases one type of man is needed to plan ahead and an entirely different type to execute the work.

"The man in the planning room, finally, whose specialty under the new type of management is planning ahead, invariably finds that the work can be done better and more economically by a subdivision of the labor, each act of each mechanic, for example, being preceded by various preparatory acts done by other men. And all of this involves, as we have said, 'an almost equal division of the responsibility and the work between the management and the workman.'"

FINAL PLEA

I have given you merely a glance at few operations, showing actual results accomplished. What has been accomplished is practically nothing as compared to what may be done.

"As yet," writes Mr. Redfield, "only the men of vision—the few far-sighted captains of industry—have grasped and acted upon this new outlook. So splendid have been the results of our industrial growth, so brilliant the victories of our manufacturers at home and abroad, so astonishing the inventive skill with which by special tools and new appliances we have reduced the cost of our productions, so matchless has been the courage with which some of us have forsaken the old and taken up the new, that we are apt to lose sight of the fact that these achievements, and this brilliancy and fine courage, have been the characteristics of the few rather than of the many, and that most of our industries are still laggards in the race."

To take a foremost place in the intense world competition that is to come after the war, we must reach the ears of the manufacturer as well as the producer and my final plea is for manufacturers and producers alike to come to their senses now at the eleventh hour and get to know themselves and their business so that Capital and Labor can deal with each other here at home fairly and squarely and meet the world's competition in the same way. The stars and stripes will then be as they should be—an emblem symbolic of a "square deal" to all.

DISCUSSION

Mr. E. O. Griffenhagen, M. W. S. E.: As I understand the argument of this paper of Mr. Lichtner's, it is to the effect that in these times we can't have very much patience with inefficiency, and I suppose we are all agreed that after the war conditions will be such that any industry that doesn't conserve time and human energy to the fullest extent will not be able to keep pace with competition.

Mr. Lichtner indicted modern business methods, and he based his criticism on the lack of respect that the modern business man has for the thinkers, as contrasted with the doers. This morning a technical magazine came to my desk which contained a foreword

by Mr. Charles W. Mears of the Winton Company on this very subject. Mr. Mears says "the American business world speaks very highly of the ability to think. The man who can think out and solve business problems is a great fellow. Board of directors, officers and managers are presumed to think, and the men and women under them are directly urged to think. Judged at a distance, "think" seems to be the key word of the business world.

"And yet I do not know a single business house that employs a single person whose sole duty it is to think.

"Usually we find that, although everybody in business is supposed to think, everybody in business is always required to do something else besides thinking, and that something else is invariably so large a part of his job that what thinking a business man is able to do amounts to a mere by-product, and generally to an inconsiderable by-product.

"If the average business man is able to think often enough, fast enough, comprehensive enough and clearly enough to keep him abreast of his day-to-day job, he feels that he has done about all that anybody has the right to expect of him."

Now, I suppose we are all familiar with men—and I know I am with a number of them myself—in big businesses, who meet the day's appointments and answer the day's letters and handle the complaints and difficulties that come up and then go home feeling very virtuous because they think they have done a very good day's work. But they haven't done a single thing, and they haven't enabled those under them to do a single thing to make the next day's work any easier.

That leads us to what I suppose is as good a distinguishing principle of this modern school of management as any, and that is the separation of the planning from the performance. That is the wonderful thing that stands out as being different from the old school of management.

I think probably the most valuable part of this very valuable paper is the recital of concrete instances of what can be accomplished by the introduction of the principles that Mr. Lichtner has outlined. They are often very hard to get at. A business man who has made big improvements of this kind is not very anxious to publish them and describe them for the benefit of the public, and few men would take the time and trouble to go into it as he has done.

Personally, I was most interested in that part of the talk that covered the establishment of principles. Mr. Lichtner explained that the principles were three in number: First, an analysis of the day in which each man's work is done; second, the training of the men to do work in the way specified, and third, the co-operation

between management and the individuals, making it possible to live up to the standards set. Those principles apply pretty closely to manufacturing industries, but they are rather hard to apply so they will meet all kinds of businesses.

I have been interested for a number of years in trying to find a good statement of the principles of business management that would apply everywhere, and I personally don't think it is entirely possible. The best attempt I have seen I found by accident in this very library. I was reading through an article written by Mr. A. Hamilton Church and Mr. Alford in the *American Machinist* of May, 1912, which discussed a series of attempts to set up some general principles. They tried to deal with the subject under three principles, of which the first is the systematic use of experience; second, the economic control of effort, and third, the promotion of personal effectiveness. They tried to explain that by the systematic use of experience they mean the bringing together and analyzing all the past methods and past attainments and the use of the method of experimentation to add to that experience where it seems that that will bring in something new and better, and finally the setting up of standards for the best way of doing the thing. That is practically the same as the first principle Mr. Lichtner has brought out.

Under the second principle, "the control of effort," they speak first of the "division of effort," which is the big problem of organization: how to take the general functions in the enterprise and divide it among the various component branches right down to the individual. The second sub-heading under that second principle is the "co-ordination of effort," which brings in the question of planning, scheduling, and despatching. It is in that second principle that modern so-called scientific management has made the biggest advance.

The first principle, the division of effort, is the old principle of the division of labor, which has been studied for a long time past.

The third matter in connection with effort is the conservation of effort, which is the whole question of what is lost motion, and the removal of resistance of all kinds, and finally, the remuneration of effort.

The third principle they don't try to elaborate. There is the problem of personnel, labor question, etc., and it has had a great deal of prominence in connection with the study of labor turn-over.

In some work I have been associated with recently this question of the promotion of personal effectiveness, the whole question of personnel, is one of the greatest importance. It must be handled in connection with the improvement of production control. In our attack on this matter of employment we considered that the question of personal effectiveness is made up of skill and effort. Skill, of course, is used in the largest sense, meaning not only our mental skill, but the benefit of applied experience and all that sort of thing.

Now in connection with the question of skill there is first a matter of securing the best fitted men or the men that we have reason to believe are going to make the best workers. Then enters the question of training, so that the skill we have to begin with can be improved and increased. Of course the modern method in that connection is to give the right initial instruction and follow it up.

Finally, there is the question of retaining that skill, which is an exceedingly important one in the question of labor turn-over. That means simply that the man must not be allowed to quit in the early days on account of misapprehension as to accidents, sickness, fear of losing his job, or prospects for the future in his work.

Then, under the heading of effort there is the whole question, positively, of providing incentives, and negatively, of removing resistance. No matter how much we theorize on the question, the strongest incentive always is the opportunity to earn more money, and the various systems must consider that question as the most important one. First of all, a fair day wage; and then the possibility of a man earning more, giving a man a bonus, perhaps, or a premium, satisfying certain conditions; and the best incentives, after all, and most modern methods of increasing production, are based in some way on that.

Removing resistance is a negative way of promoting effort. It may be a matter of physical resistance such as lack of space or poor light or heat or cold or anything that affects the well being and comfort of the man on the job. It may be a mental resistance, such as fear of his job, fear of old age, fear of disease. These things may be overcome by group insurance, sickness benefit, welfare measures, pensions and others may be called.

Now I have not very much to add to Mr. Lichtner's talk, except to say that as I said before, the examples that he has given are very important to anyone that believes it is possible to improve modern methods of management. I don't believe anybody that has worked along these lines believes there is any one principle that settles the whole thing; but there are many measures that are pretty well proved that, taken all together, constitute a program that will go a long way, if generally adopted, to bring the industrial efficiency of the country to a considerably higher standard than it has reached so far, and I think that everybody who is interested in seeing the country go ahead and meet war conditions ought to give very serious consideration to these methods when they are discussed.

Mr. Lichtner: The discussion has brought out some points which may be considered more fully.

The Bonus System is most generally used in those cases where accurate Job Analysis and Time Study have been made of the operations. I presume this is what you mean by the term "efficiency basis."

Piece Work System can be used with as great success as Bonus

System if it is properly applied, but owing to the past practice of setting very unjust Piece Work rates and then cutting the rates from time to time the workman resents, and rightly too, anything that savors of this method.

The advantages of the Bonus System of payment are:

1. Workman is given a definite, predetermined time in which to complete the job, which serves as a guide to get the correct pace at which to work.
2. It guarantees operators a Day Wage.
3. It pays a good wage for a good output.
4. It holds output to the standard as set.

A Bonus System should be so fixed that the bonus paid the workman is for increased effort and goodwill on his part. It should not be paid as a substitute for wages. In other words, if an operator fails to come up to the standard set for the particular work he is endeavoring to do, the company guarantees to pay him his hourly rate for the total time actually spent on the job. The amount of bonus earned by the workman, on the other hand, gives the Company a measure of his efficiency as well as bringing to their attention those workmen who do not come up to the standard. In this way the work of such operators can be studied to determine whether they are not fitted for the job assigned to them or whether they can be brought up to the standard by proper instruction.

In reference to the statement that if a Piece Work System were used we would run into trouble with the labor unions, while with the Bonus System this would be eliminated, I will say that labor unions do not permit their members to work under any form of payment necessitating the measuring or predetermining of the quantity of work to be done; in other words, they believe only in Day Work.

It is very essential in any control which may be devised, to record, preferably by checking or graph, the progress of the work. This may be accomplished by a so-called "Route Sheet" which gives the full specifications of the order and shows all the operations in the sequence in which they are to be performed. Each time a ticket is sent or given to the operator for a particular operation the Route Sheet or card is checked off to show that the operation is being worked on and at the same time the operator's number is entered opposite the operation. When the operator finishes the operation he returns the ticket to the Routing Department, when the Route Sheet is checked to show that the operation is completed.

It is not necessary in any case that I have ever seen to remove the stock from the machine so as to trim the various sides. This condition would only occur in case the machine was too small for the size stock cut on it. I have had cases where the size of sheets to be trimmed on all four sides was 40″ by 60″, necessitating two

men to turn the stock on the machine. The machine barely took this size sheet, requiring the pulling of the stock out in front of the knife to the front edge of the cutting table, besides bending up the corner of the stock in order to turn it 90 deg. This plan is far better than removing all the stock from the machine after the first cut and each time replacing it on the table.

The heavier the weight of the stock the smaller the quantity of sheets lifted by an operator per lift. Also, the heavier the stock the fewer the number of sheets that can be placed under the knife of a machine which takes a thickness of from 5 inches to 5½ inches. Very large, heavy weight stock, will take two men to handle it, while the lighter weight stock and smaller sizes require only one man.

The amount of Bonus or Premium must be at least 25 per cent of the Day Rate and may be as high as 100 per cent, depending upon the kind and class of work. The case cited by Mr. Parker where the bonus only amounted to from three to five dollars a month is a good illustration of the kind of work done by an amateur or by a Capitalist. These are the things that bring home forcibly to Labor that Capital is ever ready to extract the last ounce of blood from the poor workman if it is possible to do so.

In closing I would like to add a few brief remarks.

We are today facing a new problem where Labor can and is assuming a very strong position in determining the division of profits which Capital and Labor is to receive. The day of excessively large profits by Capital and comparatively small compensation for Labor belongs to the past. The question today is, how shall Labor intelligently cooperate with Capital unless it is given a voice in determining the policies which shall control our industries? While complete harmony between Capital and Labor is hardly conceivable from our present viewpoint, we are beginning to recognize that there is at least a common meeting ground for considering their differences.

First, the absolute facts in regard to any point at issue must be determined. These facts must be obtained and presented by a third party in whom the principal parties have full confidence and whose report they will accept as final.

This third party should be, therefore, a specially trained man, preferably an expert in his field of work, who knows how to probe for the real facts, and how to present them in a clear, cleancut, and concise manner. This party may be an individual, a company, or the United States Government.

The United States Government has very recently established a Bureau whose function is of this sort. On account of the vast amount of work now being done for the Government, however, this Bureau can do very little at the present time for Capital and Labor in any line of business outside of the so-called "War industries." Realizing this fact, therefore, let us, as engineers, assist the Govern-

ment in its new endeavor to bring these two factions to a better understanding than has seemed possible in the past.

We can certainly serve our country no more effectively than by the accomplishment of this end, which will inevitably mean a large increase in production along all lines of industry, and at least a partial solution for the immense problems which must be faced squarely when the nations of the world have demonstrated that might does not make right, but that in true liberty and justice only is real progress or power.

April, 1918

THE STORAGE OF BITUMINOUS COAL

By H. H. Stoek, m. w. s. e.*

Presented April 15, 1918.

Although the storage of coal has become of unusual importance under war conditions, it should not be considered only as a war expedient, and plans for the storage of coal should be made by every householder and in connection with every industry that uses coal as one of the adjustments necessary to stabilize a fundamental industry of the country.

The storage of anthracite in large amounts along the seaboard and lakes has become a definite part of the program of the anthracite carrying roads and has helped to stabilize the anthracite industry.

The demand for coal varies with the weather conditions and is largely a seasonal one, not only as regards domestic fuel, but to a certain extent in connection with fuel used for power purposes, either by railroads or in stationary boiler plants. As a result of the unequal requirements at different seasons of the year, and the failure to store coal during the periods when small amounts are used, the mines of the United States operate only about 200 days per year and the demands upon the railroads for handling coal are very unequally distributed, the greatest demand coming during the fall months when railway equipment is needed for the handling of crops and during the winter months when the expense of operating is greatest.

As a result of the reduced time of working of the mines, an extra daily wage must be paid the miner and other employes about the mine if they are to make a yearly living wage, and there must be also an excessive number of mines to take care of this peak load during a part of the year. The unequal production during different parts of the year is shown by the accompanying graph prepared by the United States Geological Survey.

The extension of the working mining year to correspond to more nearly a normal business year and the equalizing of the transportation problem for the railroads are sufficient reasons for engineers to seriously consider the storage problem, even were there no other humanitarian and commercial aspects to the problem, such as the avoidance of suffering in the homes of the country and provision against interrupted operation of industrial plants.

A reason often advanced against storage is the increased cost involved, but a suitable readjustment of mining and transportation conditions should mean a lower cost for mining and transportation that would, at least partly, offset the additional

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necessary extra cost for storage and should not increase the cost to the consumer much, if any.

Granting, then, that coal storage is advisable, by whom and where should coal be stored and is it practicable to store coal. Since the problem concerns the producer, the transportation company and the consumer of coal, whether it is the domestic or power plant consumer, the benefits and the burdens derived from the storage of coal should be shared by all of these parties concerned. In ordinary times the householder and the power plant user are interested in storage merely as a matter of personal insurance against lack of supply and they are not interested in the economic advantages that may accrue to the mining company and the railroad. Hence, any interest in storage by the war must be stimulated by sharing in any economic advantage that may come from storage and to him sharing means a money saving to himself. It is, therefore, advisable and under normal conditions necessary that a reduction in price be made during the spring and summer months to stimulate storage by the user. Many can not pay the winter coal bill in a lump sum and to provide for deferred payments the coal dealer usually adds 25 cents per ton, which nets him about 6 per cent on coal sold at $5.00 per ton. If the mine operator is to be benefited by storage through the more steady operation of the mines, he should expect to pay for this benefit by a slightly lower price during the summer and spring, and if the railroad is to benefit, it should be allowed to differentiate in freight rates during the spring and summer, and also where storage can be made only between the mine and the market a through freight rate should be granted, permitting storage at the intermediate point without losing the advantage of the through rate to the normal market.

The storage should be as near as possible and practicable to the point of actual consumption so as to assure the user of a steady supply and to avoid the extra cost and extra breakage incident to each rehandling and also so as to best utilize the transportation facilities. Storage at the point of actual consumption is, of course, frequently out of the question, for many householders have not adequate space in their cellars since in the planning of houses sufficient attention is not given to the placing of the fuel supply. In congested districts, as for instance, the loop in Chicago, space is too valuable for renting purposes to permit its use for storage, so that in these cases storage in any quantity at the point where the fuel is to be used is impracticable.

The ordinary coal dealer handles a comparatively small amount of coal, frequently not over 5,000 to 7,000 tons per year, which means that he can not install expensive storage appliances unless he combines with a number of competitors. Public utility companies, by-product coke ovens, and other metallurgical in-

dustries must store to insure continuous operation of their plants.

The railroads are interested in storage, not only as a transportation problem, but as they are the largest users of coal. In 1916 they used 136,000,000 tons of bituminous coal, or 27 per cent of the entire output. The coal mine operator is interested in storing as an operating proposition that will enable him to run his mine more days per year and per week than he is able to do under present conditions. The car supply at the mine during the early part of the week is usually better than during the latter part of the week and by placing coal in storage, he can take advantage of any extra cars that may thus be on hand. Also the demand for the different sizes of coal varies with the seasons, and by having a storage pile he is able to supply this demand to better advantage.

PRACTICABILITY OF COAL STORAGE.

The effect of storage upon coal may be considered under the following heads:

1. Appearance.
2. Loss in heat value.
3. Difference in firing qualities of stored coal.
4. Change in coking properties.
5. Change in gas-making properties.
6. Degradation, or the increase in the amount of fine coal and dust due to breakage from handling and the slacking or weathering due to exposure to the air.

The effect of storage under these various heads may be summarized as follows:

Appearance. The exterior of a pile of certain kinds of coal frequently becomes covered with a white coating of sulphate of iron or it may be rusty and very dirty in appearance. Usually this change in appearance is only skin-deep and the interior is not changed in appearance to any extent, if at all, excepting with certain slack coals. Certain coals have much dirtier appearance in the piles after being in storage, and although the heat value is not deteriorated thereby the sale value may be decreased, because, with the domestic user, particularly, the appearance of the coal means a great deal.

Loss of Heat Value. The loss in heat value, due to storage, is much less than is commonly thought. It varies with different coals and is greater for screenings than for screened coal. Experiments by Professor S. W. Parr, University of Illinois, show a loss of only 3 to 3½ per cent for screenings and also that coals vary in this respect. Those from southern Illinois show less change than those from central Illinois; also coals that show a small decrease at first continue to have only a small decrease

as time goes on. These experiments are substantiated by tests made by Mr. A. Bement, noted in *Black Diamond*, April 17, 1917, and similar tests made by the U. S. Bureau of Mines, noted in Bulletin 136.

It is difficult to differentiate between losses in stored coal due to the natural weathering and deterioration and those due to incipient or actual spontaneous combustion; also between losses in heat value and losses in coking, gas-making and other properties.

There is a general and widespread opinion that stored coal is dead when put on the fire and is often considered and condemned as being "no good." Some, however, claim that stored coal burns better than fresh coal, but this is doubtful. Although there is no great decrease in calorific power, it is quite probable that, due to the oxidation of the surfaces of the lumps of coal, they burn less freely, but experiments made at the University of Illinois on a stationary boiler showed that the stored coals tested had an equal evaporating power with the fresh coal, providing a thinner bed was carried and greater draft furnished. In locomotive practice stored coal undoubtedly gives slower and less efficient results if the stored coal has broken down much during storage, because in that case a much larger per cent of the fuel goes up the stack without actually burning, and the draft cannot be varied as is the case with a stationary boiler.

Spontaneous Combustion. The greatest objection to storing coal is the liability to spontaneous combustion and on this point there is a great deal of misapprehension. Before any coal is stored the question should be very carefully considered and studied, both as to the coal to be stored and more particularly the method of storing. Spontaneous combustion is due mainly to the oxidation of the carbon and other organic materials in the coal and to a less extent to the oxidation of the sulphur in the iron pyrites contained in most coals. Freshly mined coal has a tendency to oxidize and heat, and while this property varies with different coals, the general rule apparently holds for all coals. The finer the coal the greater the surface exposed to the air; hence, the greater the tendency to oxidation and heating. Therefore, lump coal is not so likely to fire as fine coal, slack or run-of-mine. Any method of storage must either prevent or check the absorption of oxygen to such an extent that the generation of heat may not proceed so rapidly as to exceed the heat lost by radiation. The greater the time that elapses between the time of mining and when it is put in storage the less the liability to firing.

High volatile matter does not increase the liability to spontaneous combustion, according to the experiments of Porter and Ovitz of the U. S. Bureau of Mines. The high volatile coals in the West are very liable to spontaneous combustion, but Porter and Ovitz conclude that this is due rather to the nature

of the volatile than to its amount. Sulphur in coal assists in spontaneous combustion by oxidizing and breaking up the coal so as to produce greater fines and also in its oxidation, heat is produced, but it is by no means the principal agent as was formerly thought. In selecting a coal for storage a low sulphur coal is to be preferred.

The effect of moisture on spontaneous combustion is a disputed point and is an unsettled question, but it is undoubtedly safer practice not to wet down coal when it is being put in storage, and if it can be avoided, do not store a layer of dry coal on a wet layer. The effect of water in helping to disintegrate high sulphur coals is undisputed.

There is very little data on the exact effect of storage on the coking properties of coal, but the general opinion is that unless the coal heats and thus changes in character, its coking properties are not materially interfered with. According to the experiments of White, the gas-making qualities of eastern coals are not decreased by storage.

It is considered by many that storage does affect the value of Middle West coals for gas-making, but they have been used for this purpose to such a slight extent until very recently that the evidence on this point is by no means conclusive. In all of these cases, however, a distinction must be made between any deterioration or change due to storage alone and the changes that may take place if heating occurs to any extent.

The degradation of coal may be due, either to handling or to weathering and the amount varies greatly with the kind of coal and with the machinery used in connection with the storage.

There is often thought to be a loss in weight of stored coal, but this is more apparent than real and may be due to the evaporation of moisture. On the other hand, there is sometimes an apparent increase in weight due mainly to carelessness in taking the coal out of storage and shovelling up the ground on which storage pile has been placed; this may also in some cases account for the poorer burning qualities of some of the stored coal.

Coal Storage Practice.

Kind and Sizes of Coal that Can Be Stored.

There is an erroneous, misleading but widespread opinion that the locality from which the coal comes determines whether or not it can be stored. One frequently hears such remarks as "Eastern coals (meaning those from Pennsylvania and West Virginia) can be easily stored but Western coals (meaning those from Illinois and Indiana) can not be and they are much more liable to spontaneous combustion." Both parts of this statement are too broad, for scientific research and the experience of those storing coal, as shown by the questionnaire sent out by the writer, agree that while there are undoubtedly inherent differences in different coals that affect their liability to spontaneous combustion and also to degradation, these differ-

ences are of less importance than the size of the coal stored and the way in which it is stored. The answers to the questionnaire indicate that nearly any coal can be stored if it is properly piled and that nearly any coal improperly stored will heat and may fire.

When should coal be stored? Preferably, during the spring and summer so as to help the railroad situation and keep the mines running during an otherwise slack period. The disadvantage of summer storage is the temperature at which the coal may be put into the pile, because the coal maintains this temperature for a considerable period, being a poor conductor of heat. One reason for storage in spring is that there is a certain amount of labor available and storage can then be more cheaply carried on.

SHAPE AND DEPTH OF PILES.

The size, shape and depth of piles depend mainly upon the appliances used for storing. Generally the piles are in the form of a cone or pyramid. The storage space should be thoroughly cleaned of debris, stumps, etc., and a dry spot should be selected, if possible. Many of the large storage piles are placed on wood or concrete floors.

There is a great difference of opinion as to the height to which coal can be safely stored and there is much misapprehension on the subject. Many would limit the pile to 10 feet in height, although many of the dock piles the 50 feet to 60 feet high, and the chief objection to high piles is the difficulty in handling and moving the coal quickly in case the temperature rises and also the difficulty of testing for an increase in temperature. The idea that firing takes place at the bottom of the pile due to the pressure and crushing on account of the height is not borne out by the facts, for as many fires seem to start near the top as near the bottom and near the outside as the inside of a pile. Since the weight of a cubic foot of broken coal is about 40 pounds, a column 50 feet high weighs only 2,000 pounds, which gives a weight of only about 14 pounds per square inch at the bottom of the pile. This is very small compared with the crushing strength of most coal even when we consider that the coal does not rest on a solid base but is supported in many cases on the points of the pieces of coal. Heating due to pressure is certainly overestimated, probably also pressure due to the weight of the overlying coal.

Ventilation of Coal Piles. It is generally accepted that if the air supply is entirely shut off from the coal, as is the case with underwater storage, spontaneous combustion cannot occur, and also it is reasonable to assume that if ample ventilation can be furnished to carry off the heat and keep down the temperature in a coal pile, spontaneous combustion will not occur. It is the intermediate condition that is dangerous; that is, enough air

to permit the coal to oxidize and heat and not enough to carry off the heat as rapidly as it is generated; hence, it is that lump coal can be safely stored, because there is good circulation through the pile. On the other hand, run-of-mine often cannot be safely stored, because there is not only then present an excessive amount of fine coal that will oxidize very readily, but the openings between the lumps are filled to a considerable extent by the fine coal, which shuts off a free circulation of air.

This also explains why alternate stratification of coarse and fine coal is undesirable and why air passages due to large lumps rolling to the bottom of the pile should be avoided, because they form a duct or chimney for an amount of air to reach the fine material inside the pile, sufficient to promote oxidation, but insufficient to keep down the temperature.

The practicability of properly ventilating a coal pile has been disputed and while the consensus of opinion in the United States is against ventilation by pipes, it is probable that many of the opinions expressed are based upon unfavorable results secured through improperly installed and inadequate ventilation schemes. Many of the so-called pipe ventilation schemes have been little more than occasional placing of a pipe into which a thermometer can be inserted to read temperatures and there are very few records in the United States of a systematic and adequate ventilation scheme being installed, because such scheme is expensive and it also undoubtedly interferes with the rapid handling of the coal.

It is contended by many that closely packed coal is so poor a conductor of heat, fire can start very close to a ventilating pipe.

Several instances of successful ventilation have been cited to the writer in connection with the railroad work in the United States and the Canadian railroads. Doctor J. B. Porter of McGill University is convinced that the method of ventilation used by the Canadian Pacific Railroad and others in Canada is efficient and entirely practicable. It is questionable whether the cooler climate of Canada has anything to do with the effective ventilation noted by Doctor Porter and data upon this subject for Illinois conditions is certainly not yet conclusive, and ventilation is a questionable experiment.

TESTING FOR FIRES.

The common methods for the testing of heating coal piles are:

1. Watching when the pile begins to steam.
2. The odor, which is either that of burning bituminous matter or burning sulphur.
3. By means of an iron rod inserted into the pile and when drawn out tested by feeling with the hand.

4. By means of the thermometer inserted into a pipe driven into the pile.
5. By spots of melted snow.

HANDLING OF FIRES.

Opinions differ widely in regard to when the temperature reaches a critical or danger point. Parr says, "Bituminous coal can be stocked without appreciable loss of heat value provided the temperature is not allowed to rise above 180° F. How close to this temperature a pile should be allowed to heat is largely a matter of judgment of those in charge of a heating pile, for if the rate of rise in temperature seems to be decreasing rather rapidly, it may be safe to allow it to approach the 180° point, but if the rise is steady and regular, it is wise to load out the pile before the danger point is reached. This rise also depends upon the means available for loading out, for at a plant equipped with large grab buckets and means for rapidly handling the coal a higher temperature can be permitted than when considerable time may be required to load out the coal. A person in charge of a certain kind of coal under certain climate conditions will soon learn what is the danger point and it is impossible to set any critical temperature that will apply to all coals under varying storage conditions. The only safe rule is to watch the temperature closely and get ready to load out when the temperature reaches 150° and to move the coal if the temperature reaches 175°.

Water has generally not proved effective in putting out fires, due, no doubt, to the fact that often it cannot be applied or is not applied in sufficient quantities to thoroughly cool the entire mass. It is the very general opinion that excepting for quite small piles which can be completely soaked, water will aggravate rather than put out a fire. Water frequently cannot reach the fire because of a layer of coke that has formed a protection about it. One large pile in Chicago was soaked as completely as possible with streams from river fire tugs and while the fire was apparently out, within two or three days it was burning as fiercely as ever. If the coal can be spread out thinly and thoroughly saturated with water, the fire can be put out, but very often there is not sufficient ground available to permit proper spreading, for which reason most of the efforts to use water have been unsuccessful.

Inert gases, such as carbon dioxide, have been tried, but no successful results have been reported, because with an outdoor pile it is impossible to confine such gases, and even with enclosed piles where this has been tried the same difficulty has been met with.

There is little danger of fires from spontaneous combustion in coal stored in ordinary house cellars, as shown by the fact that in answer to letters sent to the fire departments in the

larger cities of the state the replies received stated that no special ordinances or precautions were taken against such fires and no unusual number of fires of this nature was reported.

The condition in Chicago during the past fall is reported by Mr. J. C. McDonnell, Chief of the Bureau of Fire Prevention and Public Safety of Chicago as follows:

"Every fall we have fires due to spontaneous combustion of coal in piles, but this year they started earlier than usual. Since July 1, 1917, to date there have been 63 fires in coal piles stored outside of buildings. The quantities involved varied from 20 to 15,000 tons. In 50 cases the pile laid in the open and in 13 cases only a shelter roof was provided. There were for the same period 39 fires in coal piles inside of buildings. Thirty of these interior fires were in apartment buildings and the amounts involved varied from 5 to 1,000 tons; stored in all cases on a concrete floor. In 5 of the inside fires provision was made for ventilating the pile by means of pipes. Some of the outside piles have been burning for three months and are still on fire. One large pile at the stockyards has completely changed itself into coke. Water has no effect on these fires. All the coal was a poor grade of soft coal."

STORAGE SYSTEMS

Choice of a Storage System.

As coal is a comparatively cheap and also a bulky product, it must be handled as economically as possible and in a way to produce a minimum of breakage, because in general fine coal has a less value than coarse. Though this is a factor of decreasing importance with the increased use of fine coal in stokers, for coking, etc., it will always be of importance from the standpoint of storage, as fine coal seems to be the determining element in the spontaneous heating of a coal in storage.

Remarkable developments have been made in the design of machines intended to facilitate the loading and unloading of vessels and coal cars and also that permit the rapid handling of a pile of coal in which spontaneous combustion is feared.

In the choice of a storage system the following points must be considered:

1. The location, size and topography of the available storage ground.
2. The capacity of the desired installation; that is, the amount of coal that can be loaded and unloaded in a given time.
3. The cost of the necessary plant.
4. The cost of maintenance.
5. Cost of operation.
6. The amount of breakage due to handling of the coal.

7. Way in which coal is received, in open cars or box cars, or in boats. If coal is received in box cars, buckets cannot be used for loading and unloading.
8. Length of time coal must be kept in storage.
9. Climate. In a cold climate under water storage is impracticable for most of the year.

The requirements of an ideal plant are:

(1) Adequate ground area, so that several sizes and varieties of coal can be kept separate in storage. Although the ideal of keeping the different sizes separate is not of the same importance for bituminous coal as for anthracite, it is becoming more so due to the increasing attention that is being given to preparation of coal for domestic use.

(2) Adequate facilities for rapidly and economically transferring coal from cars or boats into storage.

(3) Adequate facilities for rapidly and economically reclaiming the coal and for rapidly moving any part of the pile that shows evidence of taking fire.

(4) Adequate track facilities for bringing coal to and taking it away from storage with gravity facilities for handling cars, if possible.

(5) Minimum breakage in handling.

(6) Facilities for rescreening the stored coal. This, of course, increases the cost.

(7) Adequate water supply nearby.

(8) Low cost of installation, maintenance and operation per ton of capacity. A storage plant is in operation very irregularly and costs are apt to be correspondingly higher due to the heavy fixed charges, such as interest and depreciation.

Few, if any, storage plants contain or require all of the ideal conditions. In a coke plant, for instance, breakage need not be considered excepting in connection with spontaneous combustion, as the coal is pulverized before charging into the ovens. Storage must be adapted to requirements and limitations that prevail in the coal yards, power plants, railroad yards, boat docks, steel plants, etc.

The following is a brief description of the principal methods of storing, the details of which will be found in a circular by the writer.*

Hand Storage.

The simplest form of storage is where the coal is dumped or shoveled from a car or cart into a pile or bunker or sometimes merely dumped on the ground near the point where it is to be used, from which pile it can be shoveled directly into the furnace, or, in larger plants, it may be taken in a wheelbarrow

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*Storage of Coal, Circular No. 6, Engineering Experiment Station, University of Illinois, Urbana, Ill.

or conveyed by a scraper or bucket line to the heating plant. The amounts thus stored are comparatively small and under this head come most of the domestic storage and that used in the retail coal yards and in smaller power plants. The cost of such storage is usually inseparable from the other costs of operating the plant.

Storage by a Motor Truck.

An interesting experiment has been carried on at the University of Illinois in the stocking of No. 6 Illinois coal from near Georgetown. For several years it has been customary for the University to stock 4,000 to 5,000 tons on the ground in piles about 12 feet high, the coal being thrown from railroad cars

Fig. 1. Placing a Layer of Coal on Storage Pile at the University of Illinois.

onto the pile, distributed by scrapers and then hauled by wagons to the power plant. At times fires occurred in these piles. During the summer and fall of 1917, a pile of about 10,000 tons was placed on an old tennis court, which furnished a hard foundation, and piled to a depth of 10 to 12 feet, and surrounded on three sides by a plank fence 7 feet high. This storage pile is about 1,000 feet from the power plant, where the coal is received and in which is the machinery for crushing and screening when necessary prior to storage.

If the coal as received is either screenings or the size of lump desired for storing, it is elevated to a bin in the boiler

Fig. 2. Coal Storage Plat and Storage Pile at the University of Illinois.

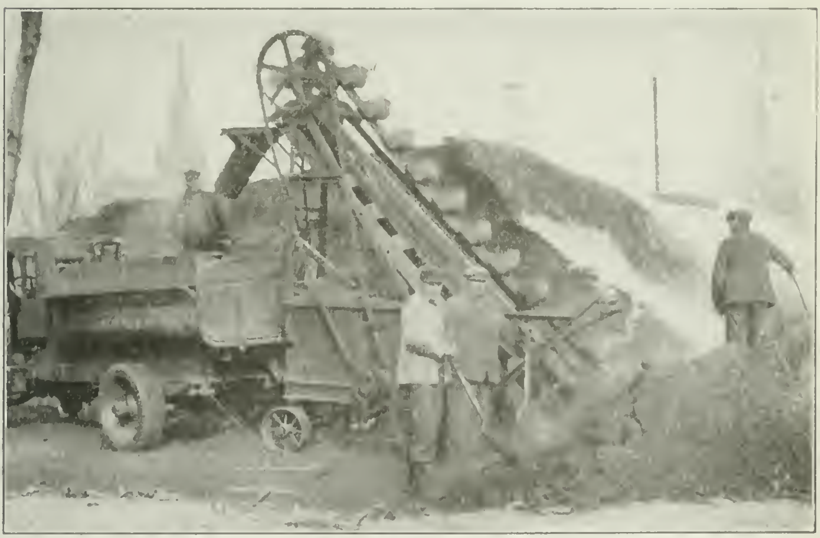

Fig. 3. Electrically Operated Wagon and Truck Loader Used at the University of Illinois.

house and thence discharged into a Republic end-dumping motor truck. If coal of the size not desired for storing is received, it is screened and, if necessary, crushed, then by means of the storage truck is taken to the storage ground (Fig. 1). At the storage plant, a truck running on the ground builds up a bed of coal 2 to 5 feet thick from the fence inward toward the center, and when the center becomes too small for the truck to be handled, it is run upon the layer already in place and a second layer similarly deposited. The truck runs on a track built of 3x4-ft. pieces of scrap plank held together by galvanized wire or cable (Fig. 2), this track being made in sections 5 to 8 feet long for easy handling and two lines being laid on which the truck runs. In this way the pile is compressed as the loaded truck runs over the top of it. The coal is unloaded by a Jeffrey wagon and truck loader, rigid type A-16, electrically operated (Fig. 3). The cost of storing and removing the coal is as follows:

COST OF STORING COAL AT TENNIS COURTS WITH TRUCK.

Truck will handle 19 tons per hour.	
Cost of hauling coal with truck	$0.08
Cost of trimming pile, building roads, etc.	.06
Cost of unloading lump coals by hand from flat bottom cars, crushing, elevating and loading truck	.20
Cost of unloading screenings by hand from flat bottom cars, elevating and loading truck	.13
Cost of unloading screenings from bottom dump cars, elevating and loading trucks	.07
Total cost of placing coal in storage	$0.21 to $0.34

COST OF REMOVING COAL FROM STORAGE WITH MOTOR TRUCK BASED ON 15 TONS PER HOUR ON TWO BLOCKS HAUL.

1 Man running loader @ 30 cents per hour	$0.30
1 Man running truck @ 30 cents per hour	.30
1 Man leveling load @ 30 cents per hour	.30
1 Man at top of pile @ 30 cents per hour	.30
2 Men at plant hopper @ 30 cents per hour	.60
2 Men at feeding loader @ 30 cents per hour	.60
Truck operation and maintenance	.60
Total cost per hour	$3.00
Cost per ton	.20
Total cost stocking and reclaiming	$0.41 to $0.54

Trestle Storage. Trestle storage consists in dumping coal from railroad cars run upon a trestle into bins or upon piles underneath. It is used extensively by large retail dealers, factories and power plants. The coal is reclaimed by hand, steam shovels, or locomotive cranes, by washing with water into conveyors, and by

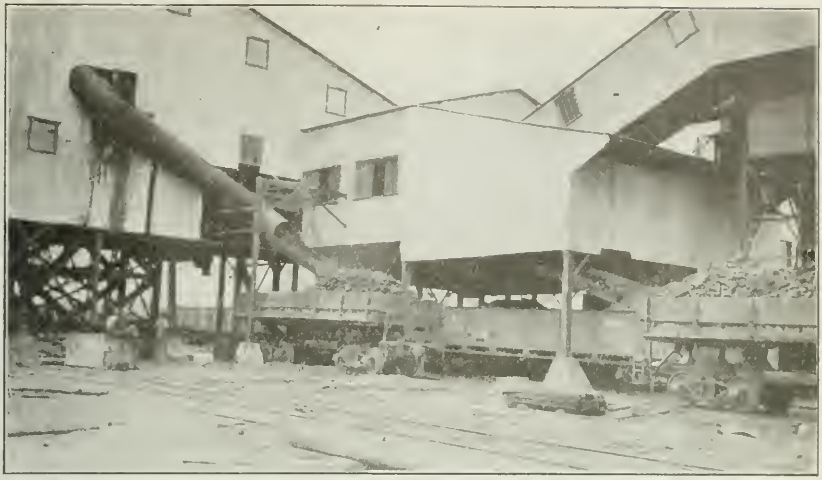

Fig. 4. Loading Dump Cars at the Tipple, Orient Mine of the Chicago, Wilmington and Franklin Coal Company.

other suitable mechanical means. Although the equipment for such storage is low in cost, breakage is apt to be excessive and the expense of unloading by hand is high unless drop bottom cars are available. It also requires considerable space if the coal cars have to be pushed up an incline by a locomotive.

There are two systems of trestle storage in which the coal is reclaimed by means of a tunnel which may be either above or

Fig. 5. Storage Track and Side Dump Cars at the Orient Mine of the Chicago, Wilmington and Franklin Coal Company.

below ground. The amount of storage space may be increased by the use of bulkheads to enclose the piles.

Storage with Side Dump Cars. Figures 4 and 5 illustrate a method of storage at the mines which has been adopted at a number of plants in southern Illinois during the past year, either in full detail as shown, or in some more simple form. The plant illustrated is that of the Chicago, Wilmington and Franklin County

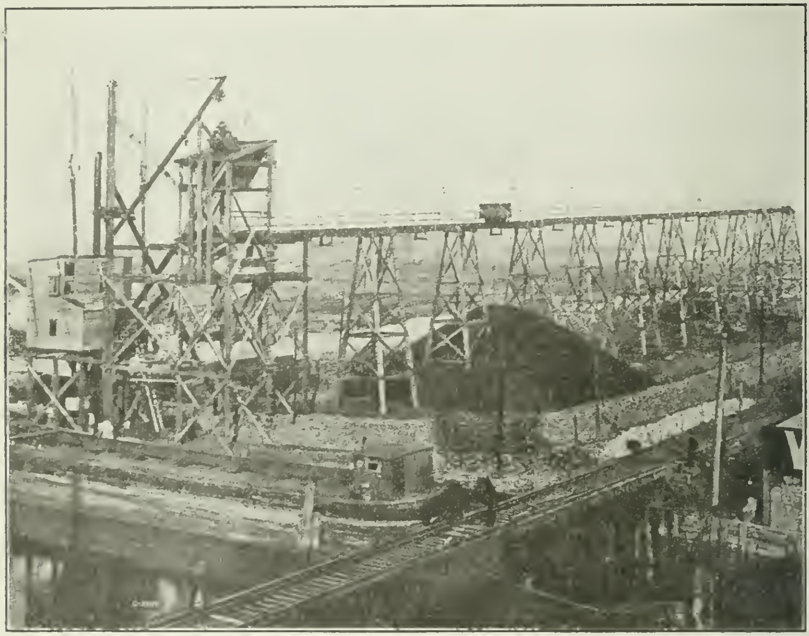

Fig. 6. Automatic Grab on Mast and Gaff with Shuttle Cable Railway.

Coal Company at Orient, Illinois. The dump cars shown with the sides built up have a capacity of 25 tons of coal. Coal from the tipple is delivered into these cars when regular shipping cars are not available and they are run up an elevated track as shown, from which the cars are dumped upon each side. One locomotive crane on each side of the trestle moves the coal into storage piles parallel to the elevated track. Regular railroad cars can be loaded by a reverse process and this is done at a number of plants where railroad coal has been stored in a similar way. At the Orient plant the reclaimed coal is delivered to the boot of an elevator which carries it back into the tipple or rescreener.

Side Hill Storage. Side hill storage has found little application in a prairie district and there are comparatively few places in which it can be conveniently and profitably used.

Mast and Gaff Storage. A simple coal handling device in connection with storage is the Mast and Gaff and an extension of this in the form of the traveling cable-way has been frequently used, particularly in connection with power plant storage. Fig. 6.

Locomotive Crane Storage. The device most generally used for storage in comparatively low piles is the revolving locomotive crane usually equipped with a clam shell bucket. This is particularly applicable at industrial plants where the crane serves a

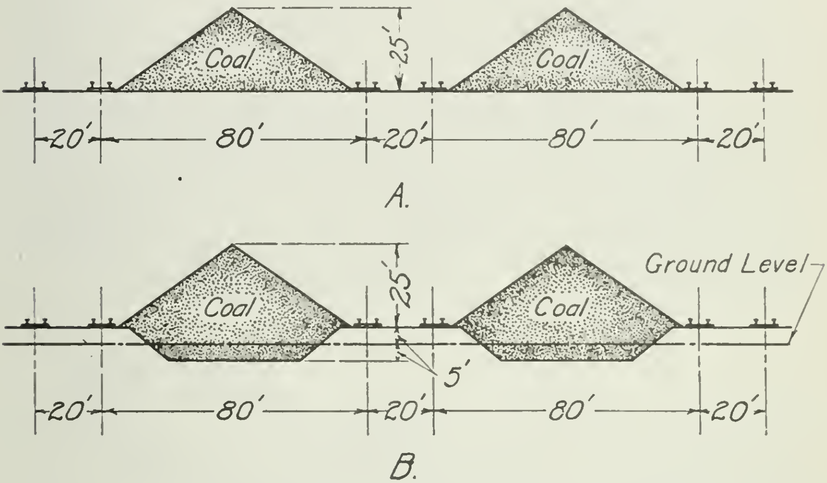

Fig. 7. Arrangement of Tracks and Storage Piles Employed by the Commonwealth Edison Company in Open Storage.

number of other purposes, because the coal storage is apt to be an intermittent operation. The coal yards of the Commonwealth Edison Company in Chicago have a locomotive crane with a 2-yard clam shell bucket which unloads from 10 to 15 cars a day of 8 hours. One operator has loaded as many as 25 cars in 10 hours, the amount being less in cold weather and in handling large sized coal. The estimated cost is 5 cents per ton for unloading and 5 cents for reclaiming for labor and materials only. The Edison Company has stored at its various city stations 100 to 150,000 tons and at the Glen storage plant outside of the city limits about 260,000 tons. Some of this coal has been in storage for 8 years without firing and the chief engineer of the Commonwealth Edison Company, W. L. Abbott, has given the following conclusions, based upon storage of all varieties of Illinois coal over long periods:

"Nearly any coal which has gone over a 1½-inch screen can be stored." "Any size of coal with duff left in will heat."

"Pea coal (over ½-inch through ¾-inch) has been in storage for more than a year without heating. Coal with screenings removed has been kept in storage 8 years without firing."

According to the scheme devised by Mr. Abbott, the coal is stored on the ground in continuous pyramidal piles 25 feet high, each pile being between two pairs of railroad tracks as shown in figure 7a, the tracks surrounding the pile being 80 feet center to center and the tracks between the piles 20 feet center to center. The crane can operate from either track while unloading or loading cars on the parallel track. The cars contain about 30 tons per foot of length. Fig. 7b shows a new form of storage pile devised by Mr. Abbott.

Circular Storage. The peculiar adaptability of the locomotive crane to operation in a circle and its easy portability have led

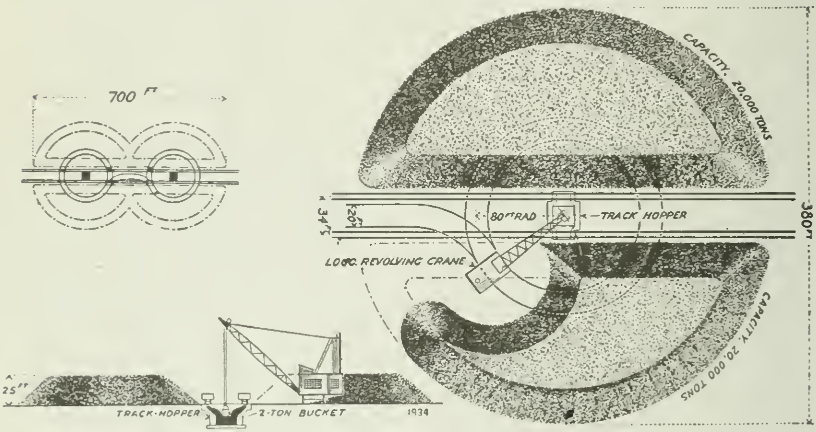

Fig. 8. Dodge Type of Circular Storage System.

to a number of so-called circular storage systems, some of which have been patented by the J. M. Dodge Company. Figure 8 illustrates one of these circular storage systems. The storage plant of the Old Ben Coal Corporation at West Frankfort, Franklin County, Illinois, is an adaptation of the circular storage system to mining conditions. At this mine five sizes of coal are prepared for the market by means of spiralizers and seven sizes are shipped. Where no cars are available for direct shipment the coal instead of being deposited in shipping bins is carried by an apron conveyor and deposited upon a pile outside the rescreening plant from which it is taken by a locomotive crane, having an operating radius of 100 feet and deposited in an elliptical pile having a capacity of 300,000 tons.

Steeple Storage. Instead of a locomotive crane a steeple tower of steel or wood is sometimes used. The boom from such a tower projects over a vessel or car and from it the bucket is lowered and after being hoisted it is drawn back and dumped into the pocket.

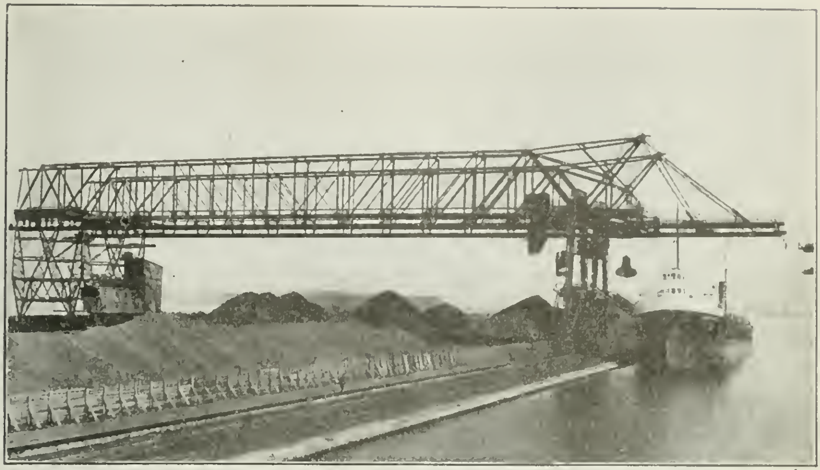

Fig. 9. Coal Handling Plant of the Reiss Coal Company at Superior, Wisconsin.

Fig. 10. Pivoted Bridge of the Milwaukee Coke and Gas Company.

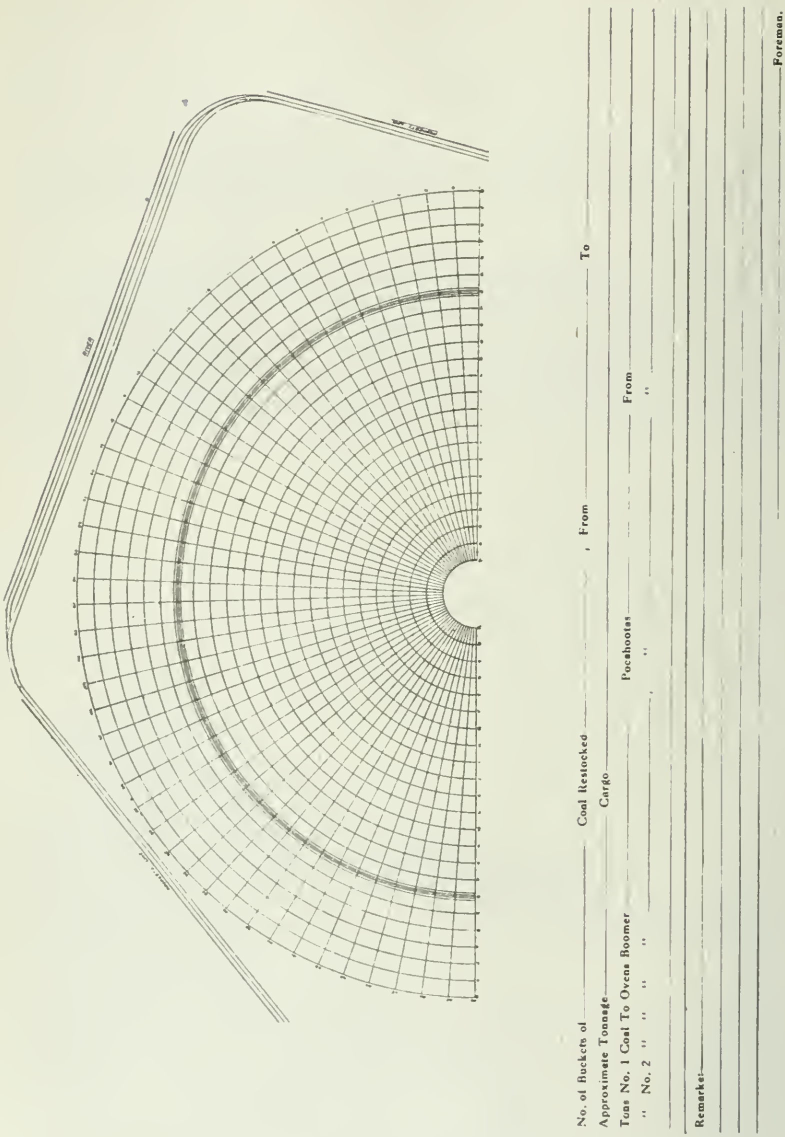

Fig. 11. Plan of Storage and Method of Keeping Track of Amount Stored.

Bridge Storage. A common form of transfer and storage for large quantities of coal is a steel bridge which is movable about the storage yard and serves as a support for a cable bucket belt or conveying device. Both ends of the bridge may be movable

Fig. 12. Reinforced Concrete Storage Bins of F. W. Stock and Sons, Hillsdale, Michigan, Designed and Built by Macdonald Engineering Company, Chicago.

in straight lines, when it becomes a gantry crane and may thus be made to cover any length of dock or storage yard, Fig. 9, or, the bridge may revolve about one end as a pivot and the storage space thus be made circular, Fig. 10.

A combination of an unloading tower and a traveling bridge utilizes to the fullest extent the storage space available. Either steam or electricity is used for the motive power and bridges may

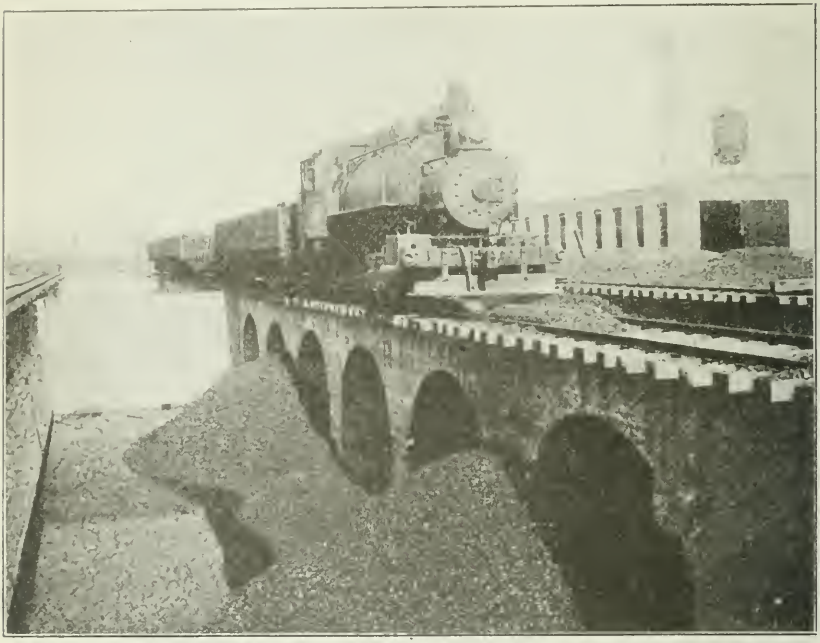

Fig. 13. View of the Under-Water Storage Pit of the Western Electric Company at Hawthorne, Illinois.

be divided into four classes according to method of handling the coal on the bridge.

1. Rope trolley in which the bucket is operated from a stationary house on the bridge.

2. Man trolley in which the bucket is operated directly from a moving cab.

3. Belt conveyor type in which the bridge serves as a support and by means of a one-yard dipper dumps the coal at any desired point.

4. A cable road bridge on which a small side dump car runs and dumps the coal at any desired point.

A pivoted bridge built for the Milwaukee Coke and Gas Company is shown in Figure 10 and the method of keeping track of the coal stored is shown by Figure 11.

Storage bins of concrete have recently come into use. Figure 12 shows two of these at Hillsdale, Michigan. A proposed system of ground storage by means of movable belt conveyors has been

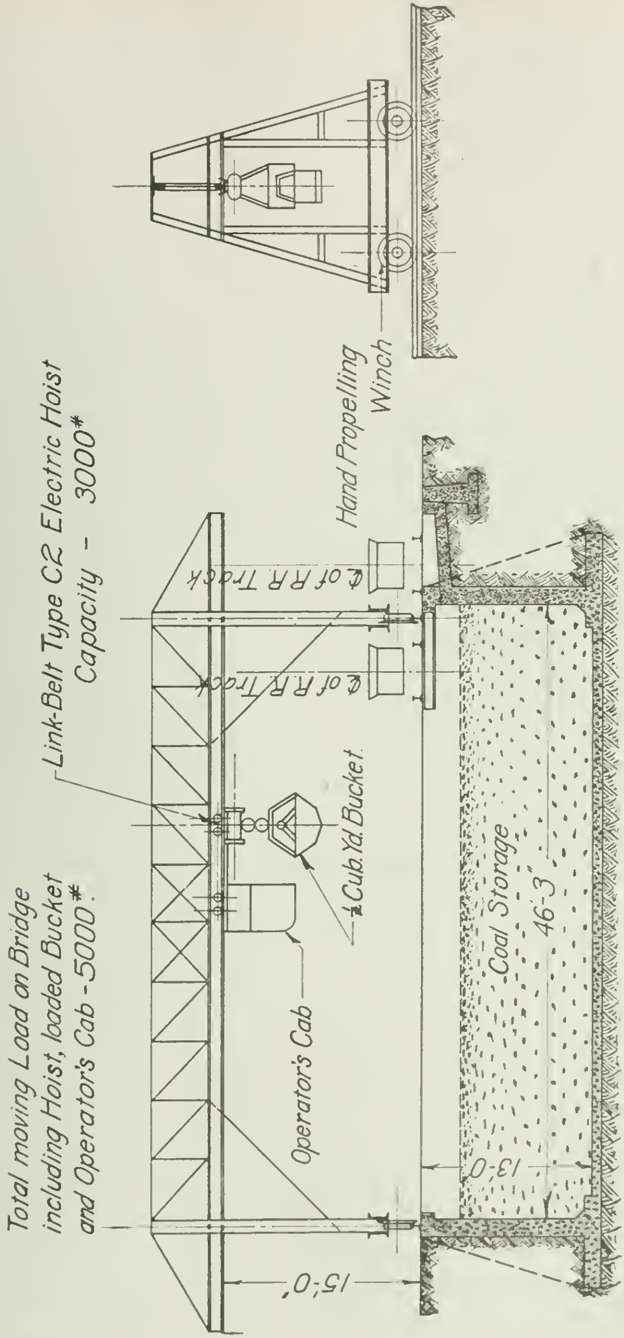

Fig. 14. Storage Pit and Bridge of the Western Clock Works.

proposed. This, so far as the writer knows, has not been put into operation as a storage device, although the principles have been used in loading vessels at Baltimore.

Under Water Storage. Under water storage has been adopted to a very considerable extent during the past few years, because the danger of spontaneous combustion is thus entirely eliminated. The method has thus far been applied exclusively to screenings. The principal objection to under water storage has been the cost of preparing a suitable pit in which to place the coal. Old quarries, abandoned clay pits, and even prairie sloughs have been used for this purpose. The Western Electric Company of Chicago was a pioneer in this method and its Hawthorne plant is shown in Fig. 13. A more recent small plant is that of the Western Clock Works at Peru, Illinois, shown in Figure 14. The most extensive under water plant of the kind yet projected is that of the Standard Oil Company at Whiting, Indiana, now being built to store 100,000 tons. One of the most complete plants is that of the New Kentucky Coal Company at Kankakee, Illinois.

The preceding are but a few of the many coal storage installations that are now operating, but they illustrate most of the types. Space will not permit of a detailed description of the operation of these and other plants, many of which are fully described in the circular already referred to.

Costs of storage may be considered under the following heads:

Cost of—	Storing	Reclaiming
Overhead	......	....
Labor	......	....
Supplies	......	....
Depreciation on Mechanical Equipment	......	....
Interest on Investment	......	....
Rental on Land on Which Coal Is Stored	......	....
Insurance on Equipment	......	....
Insurance on Coal	......	....
Total	......	....

The following costs of storage have been furnished by different companies, but it is difficult to make an intelligent comparison of them without a detailed description of the exact method of storage as given in the circular above noted.

In very few cases was it possible to secure such detailed information. Frequently costs given evidently include only labor and supplies with no allowance for overhead, insurance either on equipment or coal, rental for the land on which the coal is stored, depreciation or any interest on the investment. Many of the answers received state that it is impossible to segregate costs for the storage from other costs of handling coal and materials.

HAND STORAGE.

	Storing	Reclaiming	Total
Bohmer Coal Co., St. Louis, stored on ground and reclaimed by hand shoveling	..	....	.15–30c
St. Bernard Mining Co., Nashville, Tenn., dumped from wagons; reclaimed directly into wagons	22c	....	......
Polar Wave Ice & Fuel Co., St. Louis, hand labor	48c	16c	64c
Crystal Ice & Fuel Co., Danville, Ill. Stored in bins by dumping; reclaimed by shoveling	..	....	17c
Ebner Ice & Cold Storage Co., Vincennes, Ind. By hand labor and convey ors .154c For depreciation and interest also under water .214			$.368
Rock Island Fuel Co., Rock Island, Ill. Labor only	8c	10c	18c
Univ. of Ill. Motor truck and hand..	...	....	21–34c
Side Hill Storage, estimated in 1917.	..	....	19c

LOCOMOTIVE CRANE.

	Storing	Reclaiming	Total
Estimated cost of operating locomotive crane, $1.50 per hour, or 3c per ton.			
A large wholesale and retail coal company.	.015	.02	.095*
Commonwealth Edison Co., Chicago. Labor and materials only	.05	.05	.10
Clinchfield Fuel Co., Dante, Va. Crane and trestle	.0671	.0655	.1326
A large wholesale and retail company....	..	....	.04–.20
Pittsburgh Plate Glass Co., Crystal City, Mo.	.25	.25	.50
Rockford Electric Co., Rockford, Ill....	.10	.10	.20
American Zinc Co., E. St. Louis, Ill.....	.20	.15	.35
Mineral Point Zinc Co., Depue, Ill......	.05–.06	.05–.06	.10–.12
Crerar-Clinch & Co., Chicago. Hand and locomotive crane	..	....	.25
Estimate by C. G. Hall	..	....	.2628
Mo., Kans. & Texas Ry., including cost of track	.035	.035	.07
Chicago, Lake Shore & S. Bend Ry.....	..	....	.12
Grand Trunk Pacific Ry.............	.08	.062	.142

*This total includes .04 for interest and .02 for depreciation.

	Storing	Reclaiming	Total
Atlantic Coast Line	..	....	.04–.05
Central of Georgia Railroad	.0258	.0209	.0467
STEAM SHOVEL.			
Union Light & Power Co., of St. Louis. Dumped by hand; reloaded by steam shovel	.10	.10	.20
BRIDGE STORAGE.			
Wisconsin Gas & Electric Co., Racine, Wis.	.08	.22	.30
Berwind Fuel Co., Duluth, Minn	..	....	.60
Link Belt Co., estimate for bridge storage	.056	.0515	.1075
Calumet & Hecla Mining Co., Calumet, Mich. Hunt system, steam shovel,			
Summer	.15	.07½	.22½
Winter	.15	.11¼	.26¼
Large swivel bridge	..	.06	....
UNDER WATER STORAGE.			
New Kentucky Coal Co., Kankakee, Ill. Storage of 250,000 tons	$20,000.–$30.000		
Metropolitan Water District, Omaha, Neb.	.063	.063	.126
C. G. Hall Estimate	..	....	.1823
Peabody Coal Co., Lemont, Ill. Estimated cost of operation	..	....	.162
Estimated cost of equipment	$13,830.		
Western Electric Co., Chicago	.05	.04	.09
National Zinc Co., Springfield, Ill., 1913	..	....	.225
1917	.10	.10	.20

As the result of a rather detailed study of a number of storage plants and as a digest of the opinions expressed in answer to a questionnaire sent to a large number of those who have had extended experience in storing coal, the following have been decided upon as conclusions that are justified by present storage practice:

PRACTICABILITY OF STORING BITUMINOUS COAL.

(1) It is practicable, advisable and advantageous to store bituminous coal not only during war times, but also under normal conditions either at the mines, near the point where it is to be used; or at some intermediate point. It is well to store coal as near the point of consumption as possible to avoid rehandling.

The Reasons for Storing Coal are:

(a) To insure the fuel consumer of a supply of coal at all times.

(b) To take advantage of lower freight rates, or of lower prices of the coal at certain seasons of the year.

(c) To permit the railroads to utilize their cars and equipment to the best advantage.

(d) To permit the mines to be operated more steadily.

(2) *Kinds and Sizes of Coal that Can Be Stored:*

(a) Although it is undoubtedly true that some coals may be stored with greater safety than others, the danger from spontaneous combustion is due more to improper piling coal than it is to the kind of coal stored.

(b) Most varieties of bituminous coal can be stored in the air if of proper size and if free from fine coal and dust. The coal must be so handled that dust and small coal are not produced in excessive amounts during the storing, because spontaneous combustion is due mainly to the oxidation of the coal surface.

All varieties of bituminous coal can be stored under water which excludes the air and prevents spontaneous combustion.

The danger of spontaneous combustion in storing the coal is very greatly reduced if not entirely eliminated by storing only lump coal from which the dust and fine coal have been removed. Of two coals the least friable should be chosen for storage purposes, because less dust and fine coal will be produced in its handling.

(a) By preventing air currents through the pile by means of a closely sealed wall built around the pile.

(b) By closely packing the fine coal. Such a coal pile must be closely watched for heating. Piles of slack must be very closely watched for heating and means provided for promptly moving the pile if heating develops. The only absolutely safe way to store slack or fine coal is under water.

(c) Fine coal or slack has sometimes been successfully stored:

(d) Many varieties of mine run coal cannot be stored safely because of fine coal and dust mixed with the lumps.

(e) Coal exposed to the air for some time many become "seasoned" and thus may be less liable to spontaneous combustion, due to the oxidation of the surface of the lumps of coal, but opinions are by no means unanimous upon this point.

(f) It is believed by many that damp coal stored on a damp base is peculiarly liable to spontaneous combustion, but the evidence on this point is by no means conclusive. It is safer not to dampen coal as or after it is placed in storage.

(3) *Effect of Sulphur on Spontaneous Combustion:* It has been shown by experimentation that the sulphur contained in coal in the form of pyrites is not the chief source of spontaneous combustion, as was formerly supposed, but the oxidation of the sulphur in the coal may assist in breaking up the lumps of coal and

thus increase the amount of fine coal, which is particularly liable to rapid oxidation. Even this latter opinion is not unanimously endorsed. In spite of experimental data showing that sulphur is not the determining element in spontanteous combustion, the opinion is very widespread that, if possible, it is well to choose a coal with low sulphur content for storage purposes.

(4) *Method of Piling Coal:*

(a) To prevent spontaneous combustion coal should be so piled that air can circulate thru it freely and thus carry off the heat due to oxidation of the carbon, or else it should be so closely piled that air cannot enter the pile and oxidize the fine coal.

(b) Stratification or segregation of fine and lump coal should be avoided since an open stratum or a chimney of coarse lumps of coal gives a passage for air to enter and come in contact with fine coal and thus to oxidize it and start combustion.

(c) If space permits, low piles are preferable, as the coal is thus more exposed to the air and better cooled than in high piles and in case of heating it can be more readily and quickly moved. A disadvantage in high piles is the greater difficulty of moving the coal quickly, if necessary. The idea that a high pile causes heating at the bottom is erroneous, since as many fires take place near the top as near the bottom and near the outside as near the interior of the pile. If possible the coal pile should be divided by alley-ways so as to facilitate rapid loading out of the coal in case of necessity so that an entire coal pile may not be endangered by a local fire.

(d) Much of the attempted ventilation of coal piles in the United States has been inadequately done by the use of only an occasional ventilation pipe which has been not much more than a place in which to insert a thermometer for reading temperatures. The practice is not advised. The practice of placing ventilating pipes close together has been used in Canada and is reported to havè been effective.

(e) Water is an effective agent in quenching fire in a coal pile if it can be applied in sufficient quantities to thoroughly cool and put out the fire, but a small amount is ineffective. Unless there is an ample supply of water to thoroughly quench the fire and cool the pile, it is very dangerous to add any water to a coal pile.

(f) Coal of different varieties should not be mixed in storage if this can be helped, for one coal that has a greater susceptibility to spontaneous combustion than the other may jeopardize the safety of other coals that are not so liable to spontaneous combustion.

(5) *Effect of Storage on Value of Coal.*

(a) The heating value of a coal as expressed in B.t.u. is decreased very little by storage, but the opinion is very wide-

spread that storage coal burns less freely when fired in a furnace. Experiments indicate that much of this can be overcome by keeping a thinner bed on the grade than is kept with fresh coal and by regulating the draft.

(b) The coking properties of most coals seem to be decreased as a result of storage.

(c) The deterioration of coal stored under water is negligible, and such coal absorbs very little extra moisture. If only part of a coal is submerged, the part exposed to the air is still liable to spontaneous combustion.

(6) *Additional Precautions.*

(a) The best preventive of loss in coal storage is to regularly inspect the pile and if heating occurs up to 150 degrees Fahrenheit to keep very close watch on the pile and if the heating increases, to 175 or 180 degrees, to remove the coal as promptly as possible from the spot affected, and thoroughly cool it before piling it again.

(b) Storage appliances and arrangements should be so designed so as to make it possible to load out the coal quickly if necessary, and the coal should not be stored in large piles unless provision is made for loading it out quickly.

(c) Pieces of wood, greasy waste, or other easily combustible material mixed in a coal pile may form a starting point for a fire, and every effort should be made to keep such material from the coal as it is being put in storage.

(d) It is very important that coal in storage should be kept from such external sources of heating as steam pipes, because the susceptibility of coal to spontaneous combustion increases rapidly with an increase in temperature.

DISCUSSION

Andrews Allen, M. W. S. E.: The problem of storing coal is one which has to be designed to fit the conditions. The plant with which I am especially familiar and which has been mentioned by Professor Stoek was designed by the Allen and Garcia Company, together with the operating officials of the Chicago, Wilmington and Franklin Coal Company for their Orient mine at West Frankfort, Franklin County, Illinois.

The purpose of the plant was to store coal at the mine in order to equalize the car supply and the requirements of the market. In order to meet the requirements of the case it was manifestly necessary to handle the coal very rapidly into storage, as it might be necessary to run the entire product of the mine into storage for half a day at a stretch without slowing up the operation. This means handling some twenty-five hundred tons in four hours or less. The recovery capacity was fixed at 500 tons per hour for

reprocessing. The recovery capacity for mine run is limited only by the capacity of the cranes.

It was not considered practicable to store the separate prepared sizes, and then recover them, without reprocessing, because the coal is quite friable and the degradation would injure the product and also because it would be quite a complicated problem to handle the different sizes of coal on the four tracks on which they are produced. Therefore, it was decided to store mine run coal and for that purpose the company purchased a fleet of about 20 side-dump cars of 25-ton capacity, and two locomotive cranes equipped with clam shell buckets. The cars are operated in two trains of about 10 cars each alternately from the tipple to storage and return and are handled by a couple of switch engines which were already in service at the mine. A storage trestle about 1,100 ft. long and 10 ft. high was erected on a piece of level ground about half a mile down track from the mine. The cars are run out onto the trestle and dumped on either side up to the capacity of the trestle. Then the locomotive cranes rehandle the coal if more storage is required. In recovering the coal the process is reversed. The cranes pick it up directly into railroad cars if the coal is to be sold as mine run or into the side dump cars again if the coal is to be reprocessed.

The reprocessing plant consists of a hopper and feeder located alongside of a new track just north of the tipple. The hopper is arranged to receive the coal from the side dump cars which are dropped by gravity and dumped without uncoupling.

The feeder consists of a heavy pan conveyor moving at one-third the speed of the flight conveyor to which it delivers. The flight conveyor takes the coal to a point in line with the shaker screen and delivers it to another flight conveyor which runs longitudinally over the screens and delivers the coal to the feeder. The operation is arranged with differential speeds so the capacity can be varied from something like 50 or 60 tons an hour to 500 tons an hour. It is the intention of the company to keep the recovering plant running constantly at slow speed so that the capacity of the screens would not be exceeded when the plant is operating to its full capacity. Whenever there is a delay in hoisting the plant is immediately speeded up and in this way a uniform capacity maintained. When they have an accumulation of stored coal and a surplus of cars they work the plant after hours and on Sundays at maximum capacity to catch up. At the time we discussed this arrangement, the plan of side-hill storage was also discussed, but the advantages of hillside location were small and the capacity was limited on account of the difficulty of getting height enough to operate by gravity without excessive grades and prohibitive cost. So we decided to sacrifice the advantage of the side-hill storage for the greater capacity of the level trestle storage. We also figured over all kinds of conveyor schemes, coal bridges and bins, but dis-

carded them all for various reasons, principally lack of capacity, prohibitive cost or unfavorable local conditions. The plant has been very satisfactory and we have seen no reason to regret our decision. The storage plant has now been in operation for about nine months and has very much more than paid for itself; it has been an extremely valuable asset to the company.

Just one more consideration of a general nature. If one considers the general proposition of operating a large coal mine, one realizes that it is almost a class by itself, in that the operation is conducted on what might be called a "shoestring basis." You must have railroad cars on the proper tracks, at the proper time, or the mine is down and when you are making the prepared sizes you must have cars not only on one track but on many tracks. There is no manufacturing plant except a coal mine that hasn't a finished stock room for storing its product.

The whole thing must go like clockwork and when there is a slip-up, the miners must be paid a full day's wages if they have to come out before quitting time. The advantages of providing some such safety valve in the operation of a coal mine are so apparent that it seems strange that more has not been done in this direction.

Mr. W. D. Langtry: The storage of coal, we all know, of course, is very important. I believe that one of the important items that it believed in, but not understood, is the ventilation of the piles. In traveling over the country and talking with the people about storage piles, a great many of them will say: "We have put down our storage pile and are going to ventilate it this year. We had a little trouble last year and I understand that ventilating a pile will help to eliminate the trouble." When asked how they are going to do it and the method of accomplishing the desired results, their replies have led me to believe that they seem to think simply putting down a pipe or two into the coal will give them all the ventilation they need.

I ran into rather an interesting incident over in Michigan where I found a party who thought he had his storage pile amply protected. The pile was about thirty feet high and he had placed all kinds, sizes and descriptions of pipes, from boiler tubes to tiling and tin pipes, in the pile. I asked him out to the pile with me so we could look it over. I found two pipes that looked especially interesting; one was sticking out of the pile about two feet and the other about four feet. I rather unconsciously lit a cigaret and blew the smoke across the top of the lower pipe and found that the smoke was drawn inside. Then I naturally blew some smoke across the top of the pipe that was higher and the smoke was taken up into the air. Then I asked the party if he didn't want to put his nose across the higher pipe, and, to his great consternation, he drew his head back rather quickly because he got the smell of the products of combustion, which showed conclusively that he was simply get-

ting enough air into the pile to assist it in burning. He was not accomplishing the desired result, for the reason that he was simply admitting enough air in there to cause trouble later on. So to me the ventilation of the piles is one that should be very complete and careful, and enough air should be put through the pile to cool it or else one should exclude the air altogether.

In regard to Pocahontas coal, I have been given to understand that it has given some trouble from spontaneous combustion, but my experience around the country, especially in Chicago, is that this coal has not given any trouble unless the trouble has come from transmission from some other source; that is, from a hot steam pipe or something of that kind. In the ordinary piles that are carried around here by the different coal companies and in the different basements, I so far have not found any trouble from Pocahontas, although I understand there has been trouble elsewhere.

One of the worst coals to give trouble from heating has been the so-called Arkansas Smokeless coal. This coal has been giving a lot of trouble here in Chicago. It has been sold in place of Pocahontas and a great many consumers have wet the coal before putting it in their basements, and this simply has acted more or less as a match to a lot of wood. This coal seems to have all the ingredients necessary to give a lot of trouble.

J. L. Hecht, M. W. S. E.: In the Public Service Company of Northern Illinois, we have stored considerable quantities of coal, and my observation has been that we have never had a fire in a storage pile of lump coal. That is, coal which has been screened. We have had fifty-six thousand tons of coal on hand. We have not paid much attention to the height of the piles. We piled it as high as our trains could conveniently handle it. We have never stored Illinois screenings but what we expected to have a fire in it, and I believe we have always sooner or later had a fire in it. We have never attempted to ventilate the coal. We stored No. 3 Nut coal from the Carterville region, Williamson County Coal, for periods of about three to four years without any signs of heating.

James Macdonald, M. W. S. E.: There has been projected on the screen tonight a picture that I am much interested in. It shows a coal storage plant which is disposed in a vertical position as against the many examples of horizontal coal piles that has been shown. This plant was built in Michigan last year and consists of two cylinders 28′-0″ inside diameter and 70′-0″ high, built monolithic of reinforced concrete. The space between the cylinders, on each side, is reclaimed by means of a straight wall, which, with the convex surfaces of the adjacent cylinders, forms a three-cornered bin, one of which is used for the elevating machinery and the other for storage of anthracite coal. This gives the building two flat sides and semicircular ends. The receiving track has accommodation for unloading one car of coal at one time. The track hopper is of sufficient size to

permit hopper cars to be dumped from all bottom openings simultaneously. A coal crusher is installed under the hopper and the coal is conveyed to the elevator leg by means of a belt conveyor located under the hopper. The coal is delivered to the two bins by gravity from the elevator head spouting, this is also reclaimed for delivery to the boilers by spouting from the bin outlet openings to dump cars, on an industrial railway, connected with the boiler room.

The question of spontaneous combustion was very thoroughly gone into and we had about the same information as was given here this evening about the effect of storing coal in deep bins, but we worked on the theory that if we stored it without ventilation, excluding the air completely, we would have a better chance of keeping it than by trying to ventilate it in store. The bins are water-proof and we partially filled them with water, or as nearly full as the reinforcement would permit; they were not figured to stand up under hydrostatic strain all the way full. Each bin is fitted with water supply pipes so that they can be flooded if the necessity arises. Even if the water treatment is not successful, our arrangement is such that we could draw the coal off from the bins, put it in the elevator and re-elevate it up to the top. Up to the present time, we have not had any occasion to try out any of those arrangements.

The storage is fire-proof; it occupies very little space per ton of storage. It is convenient to operate and may be close to the power house. The bottom of the bins are so arranged that the coal can be drawn off through the discharge spouts and dropped into the boiler room cars. The theory that we are working on might be called a "VERTICAL THEORY." I think most of the pictures used tonight show the horizontal theory of storage. If our theory is correct, we can go to the limit of height. Besides the economy of space occupied and the elimination of labor by machinery, we feel that the arrangement gives the operator complete control over any possible rise in temperature and that by excluding the air completely the chances for spontaneous combustion will be greatly reduced.

Mr. Stoek: Mr. Coatsworth asked a question that is perfectly pertinent and a natural one. I feel that a good many of the directions that have been given are about like the old Darkey who was asked if she ever used a thermometer when she bathed the baby, and she said, "I puts the baby in, and if she gets real red I know it is too hot; if she gets blue I know it is too cold." I am afraid a lot of our suggestions are somewhat along that line, simply because we have not been paying strict attention to the various points that have been brought out.

In the matter of ventilation you have the two fundamental things that you can be certain of. In the first place, if you don't get any air to the coal you will have no combustion. If you have plenty of air to take off the heat as fast as it is generated, you will not have combustion, because the temperature will not be raised.

To play safe I should certainly avoid getting the fine coal with

the lumps if I could help it. Now, for that reason, I did make the statement that we have taken the fine coal and compressed it as much as possible, trying thereby to get rid of any air currents. We haven't done it perfectly; I think if you could get it so thoroughly compacted that you would not have the air in there, you would experience no trouble with combustion. So we are approximating storage under water, where you have no air to contend with. Whether that is going to be successful with all kinds of coal I am not going to say. We have tried it on some of the worst coal in Illinois. Personally, I wish that fence that we have around the pile there had been luted up as they have done in Milwaukee. I have a few slides showing where spontaneous combustion has set up in different places right at the foot of the posts supporting that fence, and the foot had burned through a couple of feet. I couldn't get Superintendent Billings to assent to doing that last year; he is set on trying to store the screenings without doing anything except putting up the piling and compressing the coal. And I might say also that the place where they did have the trouble was where they had other coal mixed in with it. There is a very well defined opinion amongst those who have stored coal, particularly in the last year or two, that it is not wise to mix coal; that the liabilities are much less if you keep coal separate in the storage. Now I have not been able to find in any of the literature on the subject that I have seen any reason why if you mix the coal the mixture should fire any more readily than if it is not mixed. Naturally, if the mixed coal fires it will also make the unmixed coal fire. But there is that well defined opinion, and I think we ought to take account of it. We are now taking the mixed coals and putting them together to see if we can verify this opinion.

Now I want to say we are in between those extremes. It is a thing we will have to ultimately work out in periods. It always pays to play safe in regard to these things, and I certainly would not advise taking screenings and piling them very high in any case, unless you have some appliance there for getting at it very quickly in case spontaneous combustion starts up. If you can get at it quickly enough you can scatter it and stop anything of that kind. As I have said in the paper, the safe way to store screenings is to put them under water. The under-water storage, however, is expensive and it is very frequently not practical to undertake it, but I don't think it is in many cases and it is always safe. If you have a lump coal with a lot of fine stuff mixed in with it, it is the fine stuff that starts the combustion; therefore, in handling the coal, if you start with a lump, handle it as carefully as possible so as not to make it fine. I think the more closely you can get it packed and the more you can keep the air out, the better. I think Mr. Abbott's experiênce with the Commonwealth Edison will bear me out there. He says they have stored all sizes above an inch and a half. Any size coal with duff left in it will heat. They have stored pea coal,

from one-half to three-quarters of an inch, without trouble for a period of eight months, and coal with the screenings taken out has been stored by them for eight years without any firing.

Another point which was brought out in this questionnaire was rather an outside element. That is one question in which I had a unanimous answer, that the starting point of many of these fires was apt to be a piece of waste, or even a piece of wood. A good many think that if you have a trestle going up through the pile that it is apt to start a fire. A good many of the fires can be distinctly traced to the cause from the fact that they build the coal right up against the furnace or they run a steam pipe down through the coal, and many of these fires are directly traceable to that and nothing else. I went over a good many of the piles up around the Lakes, and universally they have the same opinion you have in regard to the waste. And I think Mr. MacDonald is decidedly on the right track. I agree with him absolutely that if you keep the air out the height of the pile will have nothing to do with it, and if you can save space there, all well and good; you are working on the line of keeping out the air, and if you do it the coal is perfectly safe.

As to storing coal wet, I should say by no means do it under any circumstances. Don't wet down the coal as you put it into the cellar. If you do, you are pretty sure to have a fire. In our own towns with the high schools of both Champaign and Urbana, I know Urbana about four years ago were storing the ordinary run of mine coal; it was very dusty for the men spreading it in the bins, and they sprinkled it, and they had a good fire. They tried the same thing once or twice, and finally when they put the coal in without sprinkling they had no more trouble.

They tried the same thing in Champaign last year. They began to sprinkle it and it kept on firing. I don't mean to say that water will not put out fire., but a small amount of water on a spontaneous combustion fire of that sort is very bad. If you can get enough water in there to cool it off, all well and good, but if you have it hot in there and put water on it, you will have the coal broken up finally and it will enter into spontaneous combustion very easily, so by no means wet it down when you put it into the cellar.

A common storage by a number of people has been talked about a good deal, and I think it is one of the things we shall have to come to sooner or later. The ordinary coal dealer in the small town hasn't the size plant to warrant him going into the storage business. Take the two towns of Champaign and Urbana. They contain about twenty-five thousand people and there are twenty-one coal dealers there. There are about seventy-five to one hundred thousand tons of coal used domestically. That means they are handling about four or five thousand tons a year. There is one way out of that. In Rock Island and Davenport they have put a number of bins by some bin company and they are rented to the people for storage. That is one way out of the difficulty. Another way is a

combination of a number of small dealers for the purpose of securing storage.

Storing screened coal in the house. In answer to that, through a great part of Illinois they have started to store their coal in quantities. With us, while there is a certain amount of Pocahontas and Anthracite used, still the bulk is Illinois coal and that is stored in quantities in the cellar, anywhere from fifteen tons that the ordinary family would use up to where they store a car load at a time. They have had no trouble during the three years that I have been there, so far as I know, using just ordinary Illinois coal. I know our landlord buys the cheapest stuff he can get, judging from the fires we don't get.

As to bacterial action, I have seen the same argument to which you refer, but I have not been able to trace it. I don't know whether anything has come from it or not, but I don't think we have to go to bacteria to explain coal fires generally. I think I can usually find the cause in a steam pipe or an old rag or something of the sort.

In closing, I just want to say that the matter of keeping extraneous things out is also extremely important. One of the best instances I know of is down in Danville where there is a plant for separating the pyrites from the coal. There they have a great deal of these pyrites stored, and they have never had a fire in one of those pyrites bins, except where they have had some outside substance mixed in with the pyrites. Sulphur will have the same result also. That seems to indicate that the pyrites in itself is not an element of combustion.

If possible, the larger the coal and the less of fine stuff you have to store, the better. But by all means in storing in quantity watch it carefully, and if it begins to heat up above 150 degrees, be ready to go after it. A rule we have rather decided on as a rule-of-thumb is, when it gets to 150 degrees, get ready. Some people disagree with us and say they know they have let theirs go higher than that. That may be. If a man gets to know the coal and knows just what he can do, he may be able to take a little more chance on it, but until you know that pretty well you have got to play safe on the other side of it. And be sure there is an apparatus handy to handle it in case it does fire. Unless you have that handy, keep a low pile.

CLOSURE

Mr. Langtry and others brought out the fact that ventilation of coal piles has usually not been effective in the United States and that such ventilation has not been carefully done but in more or less of a haphazard way and it was clearly the opinion of those present that unless ventilation can be thoroughly applied it should not be attempted at all.

The fact was brought out that Arkansas so-called smokeless coal is very apt to fire. Mr. Andrews Allen described in some detail the storage plant at the Orient mine in southern Illinois. This plant

was installed to provide temporary storage on account of car shortage and, as it is not practicable to keep the sizes separate in storage, provision was made for rescreening the coal after taking it out of storage and before shipping it. Mine run coal is stored by means of side-dump contractor's cars of 25 tons capacity which dump the coal upon a storage yard in which it is moved about by two locomotive cranes. To reclaim the coal the process is reversed and the coal dumped into an ordinary hopper which delivers into a slow-moving pan conveyor which delivers it to another conveyor and ultimately to the screens. By means of differential speeds the capacity can be varied from 50 or 60 tons per hour to 400 or 500 tons per hour. Before installing this plant, side hill storage was discussed but discarded on account of lack of suitable side hill that would give adequate capacity. The plant has been in operation for about nine months and is said already to have paid for itself. The chairman of the meeting, Mr. J. L. Hecht, stated that a Public Service Company of northern Illinois during the winter of 1918 had stored about 56,000 tons of lump coal from which the dust had been removed and had no trouble with firing. The company had never attempted to ventilate coal piles and had stored No. 3 nut coal from southern Illinois for period of 3 to 4 years with no heating.

Concrete storage bins were fully discussed by Mr. Macdonald of Chicago.

Editor's Note: Illustrations used in this paper are from Circular No. 6, Engineering Experiment Station, University of Illinois.

WHAT THE WAR MEANS TO THE ENGINEER

Edward J. Mehren*

Presented December 17, 1917.

When asked to talk tonight, I delayed accepting for about two weeks, because it seemed to me to be a serious business to come here and talk upon the significance of the war to the engineer. One can't help feeling, when given an opportunity like this, that he ought to speak dogmatically—that he ought to say something he is sure is right. That thought was with me constantly while I delayed acceptance of the invitation, because, of all times, this is the one in which we canot speak dogmatically.

Who can grasp the things that we are going through and say that he can tell what the outcome will be, or what is the significance of this world catastrophe? And so I determined not to speak dogmatically, but merely make suggestions as a basis for discussion.

We are told in Treadgold's old definition that engineering is the art of directing the forces of nature for the welfare of man. That is a trite definition. I think it needs amendment. But let us accept it for the minute. The direction of the forces of nature for the uses of man has in our day become an exceedingly complicated process. We speak rather glibly of what engineering has done for the public, but do we stop to analyze how engineering touches the life of the average man? It does it in two ways. and the one that I am inclined to believe the engineer thinks most about is not the direction in which his influence is of the greatest importance to the country at large.

We think, for example, of the benefits to the public of the railroads, the wireless, the telephone, the telegraph, of the electric light. Sewerage systems and pure water supplies contribute to the safety and comfort of communities. Those things touch the life of every human being. Yet they are the effects of the engineer's work rather than engineering as you and I see it from day to day.

If we had contended ourselves, for example, in railroad work, with the crude methods in vogue in the last century, or if the incandescent light had never been improved beyond the first bulb, those things which now affect the community's life would never have come into general use. Their cost would have been prohibitive.

It was not until the engineer went back of the structures which affected the public, to the processes of manufacture and so cheapened them that we could produce electric light and transportation economically, that he came into the closest touch

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*Vice-President, General Manager, McGraw-Hill Co.

with the public. When he took responsibility for production he was forced to go into the mine and the factory and the mill, and there met men as factors in production.

What did we do with our opportunity? Our profession has confined itself almost exclusively to materials. If we want steel for any given purpose, we can specify to the last iota not only what should be in that steel, but the tests which will disclose whether we are getting what we want. So it is in almost every other line of material. We have gone into machinery and tool design until we can build a machine that can do almost anything the human mind can conceive of. On the material side of the question the engineer has gone a long distance.

But what do we know of the human factor that enters into the industrial process? If we are going to accept the great opportunity offered us, we must control industrial processes in their entirety.

In England when the war broke out it was feared that the welfare of the men and women would be affected if they continued to work on the standards then employed. The British Ministry of Munitions therefore established a Welfare Division, which has set us an example of the application of scientific and engineering methods to the human problem. They studied the six-day as compared with the seven-day week. They compared the results—the end results—in human efficiency of the eight-hour, the nine-hour and the ten-hour day. They weren't content with that. They studied the relation of heat and light ventilation and humidity to fatigue. They went to the homes of the workers and found out what grade and kind of food they ate. They studied the sanitary conditions in the homes. They started out in that Welfare Division to do as to labor what we engineers have been doing as to material, to determine every last factor in human life that affects our efficiency as workers.

There is a very good reason why we did not in the past take up the human as we did the material element. The reason is that if we start to analyze the human element and apply the scientific method, we get to a residuum that does not break down under engineering analysis—we call it human nature or psychology. There is something about the human being that we cannot express by formulæ. It was because we appreciated that there was that residuum of human nature that would not break down under our analysis that we turned it over to the rule-of-thumb man—to the foreman and manager. Whereas we had a method whereby we could discover and analyze, let us say, 75 per cent of the factors, we turned over the whole problem to a man who knew only 25 per cent of them.

The question that confronts us today is this: Are we, as engineers, to surrender a vital element in production, the human

factor, abandon that problem and continue to confine ourselves to materials and machines? If we do, we lose the greatest opportunity we ever had.

Moreover—and this, gentlemen, I consider extremely significant—the industrial world is beginning to turn to the engineer for the solution of the human problem in the industrial process.

One of the most able students of the labor problem I know is Miss Frances Kellor of New York, Vice Chairman of the Immigration Committee of the Chamber of Commerce of the United States. She has come to the conclusion that the only one that can solve the labor question is the engineer. Last week one of our men finished a trip extending from New York to St. Louis. He did nothing but examine plants in which the labor problem was believed to be well handled. He said that almost everywhere he went they were turning to the engineer for the solution of their labor problems. The people who are turning to the engineers are not themselves engineers, but business men and financiers. They are turning to the engineer because they realize that the day of rule-of-thumb methods is past.

I do not pretend to believe that we as engineers will ever be able to find a final solution of the labor problem. There is a conflict between capital and labor that will never be entirely compromised. The labor problem is one of constant adjustment and readjustment. A settlement today is not a final settlement, but an accommodation until the conditions again change.

I have talked rather at length upon a problem that apparently has no connection with the war at all. I have done so because what I have said is the thesis upon which my subsequent remarks rest. If you deny that, all the rest I have to say falls down.

Now with that background, what are the new conditions created by this world cataclysm? Are there indications of conditions after the war for which we engineers should be prepared? Are there to be changes in our social or economic or industrial structure which will affect the work of the engineer and his status? Certain things, it seems to me, are clearly indicated; others are vague.

It seems quite certain that there will be a shortage of labor after the war, due partly to death and injury and partly to the stoppage of emigration to the United States. What effect will a shortage of labor have on the work of the engineer? More work than in the past will have to be performed by machines. The problems of materials, of machines, will be more difficult than ever before, the work of the engineer accordingly more important.

Further than that, the stage is being set for the greatest drive after export trade that any nation has ever known. No matter

how long the war goes on, we are going to have more money than any other nation. Our condition is going to be better, because we were out of the struggle longer, and because our natural resources are so large. In addition to money, we will have great productive capacity. The plants we are expanding now for the manufacture of munitions will be available for peace purposes. We shall have, besides, the largest merchant marine of any nation on the globe, excepting England.

With these conditions we will start an export drive such as no nation has ever engaged in. For success, lower costs of production will be required, because security in the markets of the world depends on price. And in the struggle for low costs the engineer is a very important factor.

These, and other conditions that I cannot dwell on, will force the engineer's attention upon the perfection of industrial processes and the utmost efficiency in production. In securing higher efficiency the engineer is again face to face with the labor problem. It behooves us, therefore, to learn all we can about the labor situation. England presents some interesting experiences. After the war broke out the British Government reached an understanding with the labor unions to the effect that all existing agreements should be abrogated for the period of the war, on condition that the *statu quo ante* be restored after the conflict was over. The government also agreed that capital should not profiteer during the period of the war. To prevent that they placed an 80 per cent tax on excess war profits; that is, an industry can make only 20 per cent more than it did during the period before the war. The English worker has stuck by his agreement and we are lead to believe that conditions are fairly satisfactory. There are, however, undercurrents. There is enough unrest that Parliament appointed a committee to study the situation. In June of this year (1917) they brought in what is known as the Whitley report. There has been more or less discussion of it, and there are indications that its provisions may be adopted. It amounts to this, that labor should be given a voice in the management of the industry, as well as capital. In a word, despite the effort to stop profiteering in England, labor with all its patriotism, is coming to the point where it is demanding a voice in plant management.

What are we going to come to in this country? I do not know. I doubt whether anybody knows. Since we entered the war there have been about seventeen hundred strikes. You know and I know that the chief reason—though it is not so stated—why government control of the railroads is advocated is that the government may be able effectively to control the labor problem. The railroad interests are not strong enough to control it. If we are surprised at labor's desire in England to have a voice in the direction of industry, we should not forget that

the railroad employees in this country have been able very effectively to dictate to their employers, with the help of Congress, it is true. After the war, here, as well as in England, we may be confronted with a condition in which industry is managed not solely by the employers, but in consultation with the men who work in the plants. If labor forces such a condition of affairs it will be merely in pursuance of its desire to get its "share" of the profits of industry. What is its "share" in the industrial process? Nobody knows. It is a matter of bargaining, but in the process of bargaining labor wants to get into the management that it may know what the profits are and be in a better position to determine its "share."

Another drift of very great significance is in the credit situation. In the past credit has been in private hands. To him who had, more was given. The man with ideas and brains to back them was subservient to the man with capital. In England the government has built and is operating its own munitions plants. We are to do likewise. We are now building ships and shipyards. Public credit is being used. The New York papers within ten days carried a story, that received absolutely no comment, regarding studies being made in Washington of methods by which the government might finance those having war contracts.

The French Government is preparing to finance the rebuilding of its cities and its industries. They, too, are thinking of placing public credit at the disposal of private enterprise. In this country, if we should come out of the war bankrupt, the same condition would have to obtain.

Of what significance is this new order to the engineer? Just this, that the engineer is the man who does things, who can take an idea and make it a reality. In the past, to him was given who had. Is a future coming in which it shall be given to him who can do? If that day is coming, it means a larger opportunity for the engineer, for he is essentially the man who can take a set of conditions and work out the solution, if the problem lies in the industrial order.

One other point, gentlemen, and I will be finished.

We have been moving so fast, the changes have been so great, that we must stop now and then and look back to find out where we started from. Economically we are in a new era. The old ended on the third of April, 1917. We were a peaceful people two years ago: now we not only have conscription, but have made it a tremendous success. For two generations we fought ship subsidies; now we are building ships as fast as the space can be found to lay down the hulls. In the past we have left hands off private enterprise, except when private enterprise conflicted with the public good; today we are commandeering

and directing private enterprise. We are fixing prices. We are even preparing to extend public credit to private enterprise.

In an era such as this, can the engineering society stand still, can it continue to work on the lines of last year or the year before? When it became known in our office that I was coming to talk to you on the significance of the war to the engineer, one of my associates gave me this memorandum, with which I heartily concur:

> "The Western Society of Engineers has the best chance of any engineering society in the country to do something progressive. Engineers all over the country are looking for some central organization that will bring them together for joint consideration of their vital interests—which largely have to do with the question of making a living. Employment matters, professional conduct, unprofessional competition, exerting influence on public affairs, licensing, and a variety of questions, are concerned.
>
> "An engineering society lives for doing service to its members—that is, to the profession—and also to the public. Can the Western Society rise to this ideal?
>
> "During 1917 and probably also during 1918 and the next year things can be accomplished quickly that under other circumstances would take years or generations. There are plenty of instances of this in our national affairs during the last few months. Outgrown engineering traditions and society methods could also be reformed in thoroughgoing style by using the impetus of the present period."

This, gentlemen, is the time for a new vision as to the work of the engineering society, a re-definition, if you will, of what an engineering society should do. As in our social and political order we have done extremely radical things, so we should not fear, as professional men, or members of an engineering society, to do radical things. It will require a violation of traditions to rise to the opportunities of the hour.

About a year ago I was crossing the Hudson River on the 23rd Street Ferry from New York. As the boat swung into the stream, I heard a lady standing near me remark, "What a Fairyland!" I turned to look, and there across the mighty river were the buildings of lower Manhattan, every window lighted up and rising story by story up to the heights of the Woolworth Building. As I stood there looking at that mighty city, I could not help thinking that the engineer was responsible for it. When half an hour later I got off the train at my little station in New Jersey, I heard the thunder of the approaching night express for Buffalo, and, standing on the island platform, I watched it rush by. And as it disappeared in the distance I found myself saying that we engineers can do that sort of thing, if we can

take a vision and make it a reality, in the sense that this railroad is a reality; if we can erect on Lower Manhattan such a marvelous set of structures, what cannot the engineering profession do if it makes up its mind?

But there must be a vision. "Where there is no vision the people perish." If our profession did not have vision, how could it have accomplished what it has on Lower Manhattan?

I have tried to make suggestions for another vision here tonight. I am confident that if we get the right conception and put our shoulders to the wheel, nothing can stand in the way of our future, nor hinder the service we can render society through our impress on our industrial and civic life.

DISCUSSION

Professor F. H. Newell, M. W. S. E.: I came up from Urbana especially to hear Mr. Mehren because I knew he would say something that was well worth the trip. I feel many times repaid, especially as he has touched on subjects that have impressed me from many angles very greatly of late years since I have gone into educational work. It is now nearly three years since I came to Illinois and Urbana, and I have been impressed in looking over the engineering field that engineering organizations are far less efficient than almost any other type of organization, except, perhaps, a church.

But the point that Mr. Mehren has made I think is one which we might revisionate again and again and again. We have made the mistake of confining ourselves to the strength of materials and the inanimate forces of nature, whereas our success depends as much, if not more, upon our knowledge of human nature and upon forces as directed. Now we are not a logical people. We are a people of ideas, a people of vision, and our enemies, the Germans, I think are making the greatest mistake of assuming that we are a people of deliberate logic and they are trying to fight us on the ground that we are of the same methodical, plodding type that has given them their great success. We are not logical in our ways, and because of this, and because of men who work and because we who direct the men who work have ideals, there has come into the game a great, big, unknown, irreducible quantity that we must study and that we as engineers must take into larger account in our program if we are going to make it a success.

My thought is that every engineering society, especially the local societies, should make it their business from now on to study their own organization, their own efficiency, and try to develop a study of what we are doing and make a post-graduate course out of an engineering organization such as this.

I was particularly glad to learn that Mr. De Berard is to head a young men's movement, because salvation is coming from the young men. The young men who sit in the back of the room should

be asked, they should be forced, to come forward and take an active part in the work of the engineering society.

We have, as you know, three years in succession, what we call a Committee on Co-operation. We have been getting together and trying to start this movement of greater efficiency in the separate organizations. I think it is beginning to bring proof. One of the first results or accompaniments was the formation in New York of what we call the Engineering Council, representing the four large national engineering societies. We have had hopes that that Council would be truly representative of all engineers. I have had the honor of being a member and have gone down to New York several times at considerable expense to do what I could do to give the western viewpoint.

We should attempt to define just what is an engineer. One of the very first things the Council ran up against was an offer of co-operation with the United States Utilities Reserve. Some of them objected to tying up with the Department of Labor because the engineer is a professional man, while the Department of Labor has to do only with wage earners. I contend that the most of us are wage earners, and the quicker we recognize that fact the better it will be for the great body of engineers.

Many of you will not agree with me at all on that point, but I believe we cannot make the progress and take the stand in the work that we should until we are able to clearly define, and have in mind, what is an engineer, so that Engineering Council may, and we hope it will, give its representation to the engineering body, but whatever it does, it cannot take the place of the strong, local, autonomous society, such, for instance, as that at Cleveland, that has become a factor in the life of the city.

As Mr. Mehren said, I believe that we have here in the Western Society a need and the opportunity that is the greatest, perhaps, before the engineering profession to build up here in the central west at the headquarters, we may say, the nerve center of the union, the strongest idea of society, one that has a vision without being visionary, that will set the pace for the engineering world and bring it to a recognition, which cannot be done by the headquarters of great national societies, that, in my opinion, are too far east to really represent the great body of the American Engineers.

So that while we do not wish to in any way detract from the movement and consolidation of the great societies in New York, yet the fact that they are consolidating there, while a good thing, does not take away from our necessity here of doing our part in building up a great organization of engineers, because, after all, the societies in New York are necessarily and essentially divided. There are the Civil, the Mechanical, the Mining and the Electrical Societies. The future of the profession is going to be made by a man who is an engineer first, last and all the time, and I believe

this society is the type of society that is going to do the largest work, simply because it is not a specialized society.

I believe in the educational work we are doing we are making a great mistake in attempting to educate the youngsters as civil, mining or mechanical. They should be educated as engineers and then shown the opportunity after they get out. A large proportion of you that have graduated from an engineering college have gone into a different line of work after you left college than that which you took up while attending. I was educated along the lines of a mining engineer and I have surely gone into a different line than mining. But the strong thing is that the college education is sufficient to build up those men to the point where they could take up the kind of work that came easiest for them, and they are able to put it over successfully.

When a young man asks me about the course he should take, I say: "It doesn't make a particle of difference what course you take here just so you get a good education, because when you get out of here your opportunity will come to you in your own line for which you are best suited."

I agree with Mr. Mehren that the day is dawning of an entirely new era and that while we need not throw away the things of the past, we have got to open our eyes to the future conditions, which are entirely different from anything that has preceded.

Professor J. F. Hayford, M. W. S. E.: Professor Newell prided himself on bringing himself to the meeting. I think I can beat him in that respect. I not only brought myself, but I brought at least five others. I guaranteed to bring more than the five I brought, but if they came tonight they will hear a first-class address that they can remember. I think I proved to be a good prophet, for that is what I told them they would get if they came.

In another respect, I know that I can't keep up with Professor Newell. I can't talk as well or as much as he did, because my fire is blanketed, so to speak. Mr. Mehren has gotten me started thinking so fast that I can't talk for a while until I have had a chance to think it over. It seems to me that I have to follow Mr. Mehren all the way he has gone in his talk, because it seems to me there is no escape from his logic.

There are just two points I want to suggest. One of the points, which is merely giving my impression of the talk is this: It seems to me very clearly that if the engineers rise to their opportunity after this war that they have a tremendous opportunity, and that if they rise to the opportunity, show themselves to be the men, by taking into account the human side, that there will be a tremendous demand for engineers after this war.

Now one of the things which Mr. Mehren emphasized very strongly it seems to me was one of the most important things that the engineers must act upon—the realization that it is a part of

their job to help in controlling the human forces. As I understand the situation, it is about like this: There is about 75 per cent of the factors involved in human forces that are analyzable, but we haven't begun to work on them, and those so-called managers have not made a good beginning on those factors that are analyzable and which make about 75 per cent of the whole thing.

It seems to me when we start dealing with the human forces we should do as we do with the other parts of human works. Many of the factors can be analyzed. But what we ordinarily do with an engineering problem is to analyze the factor, do all the computing you can—then, when you have done all you can, there are some other things that depend on judgment. That is the 25 per cent.

It is clearly our business when we deal with the human problem to tackle the 75 per cent first. We must make good by undertaking the 75 per cent which we know can be solved by straight, analytical, careful, logical methods.

Mr. E. T. Howson, M. W. S. E.: I was very much impressed with the message that Mr. Mehren brought to us, and with the emphasis he placed on the labor problem. To my mind, that is the problem with which we are now confronted, and that we are going to be confronted with more and more in the very near future.

As the speaker has said, we have been primarily engineers of materials. We have very largely ignored the labor situation, the labor element, the labor feature in the cost of production. The Railroad Field, with which I am most familiar, I think has been no more lax in that regard than other fields, but it has been lax. I thought, as the speaker was commenting tonight of the situation in the railroad engineering organizations, about the three committees which the American Railroad Engineering Association has appointed on this question. Until a year ago all of those committees were interested solely in discussing materials, with the exception of two sub-committees of those committees which were assigned to the study of certain phases of the labor situation. In other words, all of those committees with the exception of two gave their entire time to the study of materials, and those two gave 80 per cent of their time to it and only 20 per cent to labor. This year, however, they have appointed one committee to study the labor situation. I think this has been largely true of other organizations.

But at the present time, serious as the material situation is, it is entirely overshadowed by conditions in the labor field. And I believe that is going to continue. It is a problem not only for the individual engineer, but it is a problem that will call for the best there is in the united minds of the engineers as a society.

CLOSURE

Mr. Mehren: It is worth while to say a word with reference to what is involved in an analysis of the human factor in industrial

operations. It can be put very aptly—get the facts. Clear away the debris and find out the truth. That is what it really amounts to.

Take the matter of labor turn-over. It runs as high as 300 or 400 per cent. But there are plants in this country that are working on a labor turn-over of only 30 per cent. I know of one that has a turn-over of only 10 per cent, which covers those that get married or who die.

How were these low percentages of turn-over secured? By intelligent analysis of the reasons why people left and the application of suitable corrective measures. Is there anything unusual about such a method of attack? No, it is what we engineers do every day.

On the matter of labor efficiency, those who initiated scientific management studies were working in the right direction. Where they have failed, it has been due largely to a lack of that judgment that Dean Hayford referred to. They tried to reduce everything to a formula and neglected the psychological or human side.

Another factor in labor efficiency is specialized education. I have been interested in the National Association of Corporation Schools, an organization which affords a forum for companies which are conducting schools for their employes. They are doing this educational work because it pays. They are substituting intelligent direction for the old plan of trusting to luck that when a man or a boy came into a plant some good-natured foreman would try to teach him to do the right thing in the right way.

Of course, any consideration of labor efficiency which fails to recognize the human side is bound to fail. The day is past when you can use labor just as you want to. Their side and their rights must be considered, and the public is backing up their contention.

I believe that we are not going to have quite the right point of view of this whole problem as a profession, until the men in the schools attack the problem and give the students some fundamental ideas of labor economics and labor history. As engineers, we need an appreciation of industrial relations, and the fundamentals should be obtained while we are still in college. I want to say to Dean Hayford and Dean Newell that they have a very real part to play in the solution of the problem which I have tried to set before you tonight.

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings.

MEETING NO. 1001, MONDAY, APRIL 1, 1918.

This was a general meeting of the Society with Mr. James N. Hatch, First Vice-President, presiding. The subject of the evening was "How American Industry Can Meet World Competition After the War," and was presented by Mr. William O. Lichtner, M. W. S. E., Consulting Engineer, Boston, Mass. There were present forty-five members and guests.

Mr. Lichtner's paper was illustrated by lantern slides, giving a very clear idea of the manner of introducing a scientific time study as a basis of applying methods of management. The paper presented results which have been obtained and the methods adopted.

MEETING NO. 1002, MONDAY, APRIL 8, 1918.

Bridge and Structural Section, Mr. G. A. Haggander, Chairman, presiding. The subject of the evening, "Stresses in Ships," was presented by Mr. Sydney V. James, Mechanical Engineer in charge of the Casualty Department of the Underwriter's Laboratory. The paper was presented in abstract, advance copies having been sent to the membership.

The paper presented the problems of ship design that have to do with the stresses in the ships. In response to questions the speaker explained the theory of stability of ships. This, however, was out outside of the paper. The meeting was attended by ninety-five members and guests. Lantern slides illustrated the paper.

MEETING NO. 1003, MONDAY, APRIL 15, 1918.

Mechanical Engineering Section, Mr. J. L. Hecht, Chairman, presided. The subject was "The Storage of Bituminous Coal." The speaker was Mr. H. H. Stoek, M. W. S. E., Professor of Mining Engineering, University of Illinois. Advance copies having been sent out, the paper was presented in abstract and illustrated by lantern slides. A resume was included of the various methods of storing coal and the success which had been obtained. The speaker clearly stated that it was possible to store bituminous coal and as a matter of patriotic duty it should be undertaken wherever possible. The meeting was attended by sixty-five members and guests.

MEETING NO. 1004, TUESDAY, APRIL 23, 1918.

This was a joint meeting of the Mechanical Engineering Section, the Electrical Engineering Section, W. S. E., the Chicago Section of the A. I. E. E. and the Chicago Section of the A. S. M. E. The members of the Mid-West Section of the Society of Automobile Engineers was invited. Mr. A. B. Bailey, Chairman Chicago Section, A. S. M. E., presided. There were present 220 members and guests.
Section, A. S. M. E., presided. There were present 220 members and guests.

Mr. C. F. Kettering, President of the Society of Automotive Engineers, spoke on the subject of "The Automobile Power Plant." Mr. Kettering gave a very clear analysis of the problems to be met in designing the modern gas engine, the quality of fuel obtainable and its affect upon the design of the gas engine.

Mr. Kettering also described quite fully the success of the Liberty Motor.

As a news item Mr. H. E. Weightman, Engineer of the American Electro-Agricultural Company of Chicago, described the method of growing crops by electricity. A two-reel film entitled "Fairy Magic" was given illustrating the method employed by the General Electric in the manufacture of incandescent lamps.

EDGAR S. NETHERCUT,
Secretary.

April, 1918

BOOK NOTICES

A Treatise on Roads and Pavements. By Ira Osborn Baker. Third Edition, 8vo. xi 67 pages. 235 figures and illustrations, 80 tables. Bound in cloth and published by John Wiley & Sons, Inc., New York. Price, $5.00.

Every line of engineering has advanced during recent years, but there is no line in which a greater change has been made than in road building. The motor car is responsible for much of this, and many localities are insisting upon improved roads, knowing that roads suitable for all the year traffic are as convenient for horse drawn vehicles and pedestrians as for motor cars.

As with the earlier editions of this book, the broad subject of Roads and Pavements is treated in an academic manner. Every type of roadway is treated in detail, usually with all its advantages and disadvantages clearly stated. It is therefore prevocative of argument, a feature of more value in the schoolroom than in practical work, and will probably be of more value to the engineer who designs or inspects the work than to the contractor.

Exceptional care has been taken to arrange the subject matter according to natural divisions, and we find the contents classed under Country Roads and Street Pavements. The first section is in turn sub-divided into chapters on Road Economics and Road Administration, Road Location, Earth, Sand, Sand-Gravel, Water-Bound Macadam, Portland-Cement-Concrete, Bituminous-Macadam-Concrete Roads. The second part relates more particularly to City Streets and is divided into chapters on Pavement Economics and Pavement Administration, Street Design, Drainage, Curbs and Gutters, Foundations, Asphalt, Brick, Stone-Block and Wood-Block Pavements.

Much more useful information is presented on methods of selecting the most suitable pavements for any particular location, while the chapters on Economics and Administration will be useful to those in the executive branch of road construction and maintenance.

C. A. M.

Topographical Drawing. By Edwin R. Stuart. 119 pages 6 by 9 inches with many illustrations, charts, diagrams and topographical map insert. Bound in cloth and published by McGraw-Hill Book Co., Inc. Price, $2.00.

Familiarity with a country is as important in peace times as it is necessary in war. Napoleon's defeat at Waterloo is said to have been caused as much by an unknown sunken road as by Wellington's army, and today the General Staff is pictured as studying maps, to learn the topographic features which may be used for offense or defense. It is essential therefore that these features be delineated according to a fixed style, so as to be clearly understood by everyone concerned.

Practically every feature shown on a map is as important in peace times as in war. Roads and bridges can be laid out only when grades and water courses are known, the country can be developed only when its general character can be studied in a systematic manner. This book therefore aims to indicate the accepted and approved standards of practice as regards the portrayal of the essential features of the territory covered, as well as the methods which combine good execution with economy of draughting time. As the book is intended as a basis for a course of instruction and practice in topographical drawing, a great deal of reference matter is included.

Among the special subjects treated in detail may be noted: Map Projection, Plotting, Lettering, Conventional Signs and Map Drawing. Authorized abbreviations are shown as are also several pages of Special Military Symbols.

C. A. M.

Journal of the
Western Society of Engineers

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THE PNEUMATIC METHOD OF CONCRETING

H. B. Kirkland, M. W. S. E.*

Presented May 13, 1918.

The Pneumatic method of mixing, conveying and placing concrete is a comparatively recent development in engineering methods

ERRATA
May, 1918, Journal, Vol. XXIII, No. 5.
At the bottom of page 319 add,

located on the air supply line leading to the lower jet, and the other on the line leading to the upper jets placed above the level of the batch.

an inverted cone surmounted by a cast steel cylinder in which the door operates. The door is operated by a small air piston which closes the flap door. The door is opened by releasing the air in the cylinder, allowing the door to drop open by its weight. At the bottom of the inverted cone chamber is a 90 degree elbow which forms the connection to the discharge pipe. The door and piston is the only moving part of the mixer and the inside contains no mechanical mixing apparatus and is entirely smooth and free from obstructions. The main air jet is located at the heel of the bottom elbow of the mixer. This jet is the main means of conveying and mixing the concrete. It is supplemented by air jets located at top of the mixer. The main air jet is directed into the center of the discharge pipe where it catches the material as it falls from the cone-shaped hopper above. The upper air jets create a pressure from above the batch, forcing it downward into the discharge pipe where it is caught by the main jet. To admit air to the mixer, two valves are used, one

*President and Chief Engineer Concrete Mixing and Placing Co., Chicago.

BOOK NOTICES

A Treatise on Roads and Pavements. By Ira Osborn Baker. Third Edition, 8vo. xi 67 pages. 235 figures and illustrations, 80 tables. Bound in cloth and published by John Wiley & Sons, Inc., New York. Price, $5.00.

Every line of engineering has advanced during recent years, but there is no line in which a greater change has been made than in road building. The motor car is responsible for much of this, and many localities are insisting upon improved roads, knowing that roads suitable for all the year traffic are as convenient for horse drawn vehicles and pedestrians as for motor cars.

As with the earlier editions of this book, the broad subject of Roads and Pavements is treated in an academic manner. Every type of roadway is treated in detail, usually with all its advantages and disadvantages clearly stated. It is therefore prevocative of argument, a feature of more value in the schoolroom than in practical work, and will probably be of more value to the engineer who designs or inspects the work than to the contractor.

Exceptional care has been tal...

..., diagrams and topographical map insert. Bound in cloth and published by McGraw-Hill Book Co., Inc. Price, $2.00.

Familiarity with a country is as important in peace times as it is necessary in war. Napoleon's defeat at Waterloo is said to have been caused as much by an unknown sunken road as by Wellington's army, and today the General Staff is pictured as studying maps, to learn the topographic features which may be used for offense or defense. It is essential therefore that these features be delineated according to a fixed style, so as to be clearly understood by everyone concerned.

Practically every feature shown on a map is as important in peace times as in war. Roads and bridges can be laid out only when grades and water courses are known, the country can be developed only when its general character can be studied in a systematic manner. This book therefore aims to indicate the accepted and approved standards of practice as regards the portrayal of the essential features of the territory covered, as well as the methods which combine good execution with economy of draughting time. As the book is intended as a basis for a course of instruction and practice in topographical drawing, a great deal of reference matter is included.

Among the special subjects treated in detail may be noted: Map Projection, Plotting, Lettering, Conventional Signs and Map Drawing. Authorized abbreviations are shown as are also several pages of Special Military Symbols. C. A. M.

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THE PNEUMATIC METHOD OF CONCRETING

H. B. Kirkland, M. W. S. E.*

Presented May 13, 1918.

The Pneumatic method of mixing, conveying and placing concrete is a comparatively recent development in engineering methods of construction. This method should not be confused with the Cement Gun process, which is a plastering process and is entirely different in operation and purpose. Both methods are patented. The Pneumatic method is adapted for heavy, difficult concrete work, using ordinary ingredients with aggregates up to 4 or 4½ inches in diameter.

Briefly described, this method consists simply in blowing batches of concrete through a pipe from a central point of supplies to their place in the concrete forms. The materials for a batch of concrete (½ cu. yd.) are proportioned in a measuring device and dropped into the pneumatic mixer without previous mixture.

The plant for pneumatic mixing and placing consists of (1) a mixer, (2) a pipe-conveying system, and (3) a compressed air plant.

Mixer: The mixer consists of a steel shell having the shape of an inverted cone surmounted by a cast steel cylinder in which the door operates. The door is operated by a small air piston which closes the flap door. The door is opened by releasing the air in the cylinder, allowing the door to drop open by its weight. At the bottom of the inverted cone chamber is a 90 degree elbow which forms the connection to the discharge pipe. The door and piston is the only moving part of the mixer and the inside contains no mechanical mixing apparatus and is entirely smooth and free from obstructions. The main air jet is located at the heel of the bottom elbow of the mixer. This jet is the main means of conveying and mixing the concrete. It is supplemented by air jets located at top of the mixer. The main air jet is directed into the center of the discharge pipe where it catches the material as it falls from the cone-shaped hopper above. The upper air jets create a pressure from above the batch, forcing it downward into the discharge pipe where it is caught by the main jet. To admit air to the mixer, two valves are used, one

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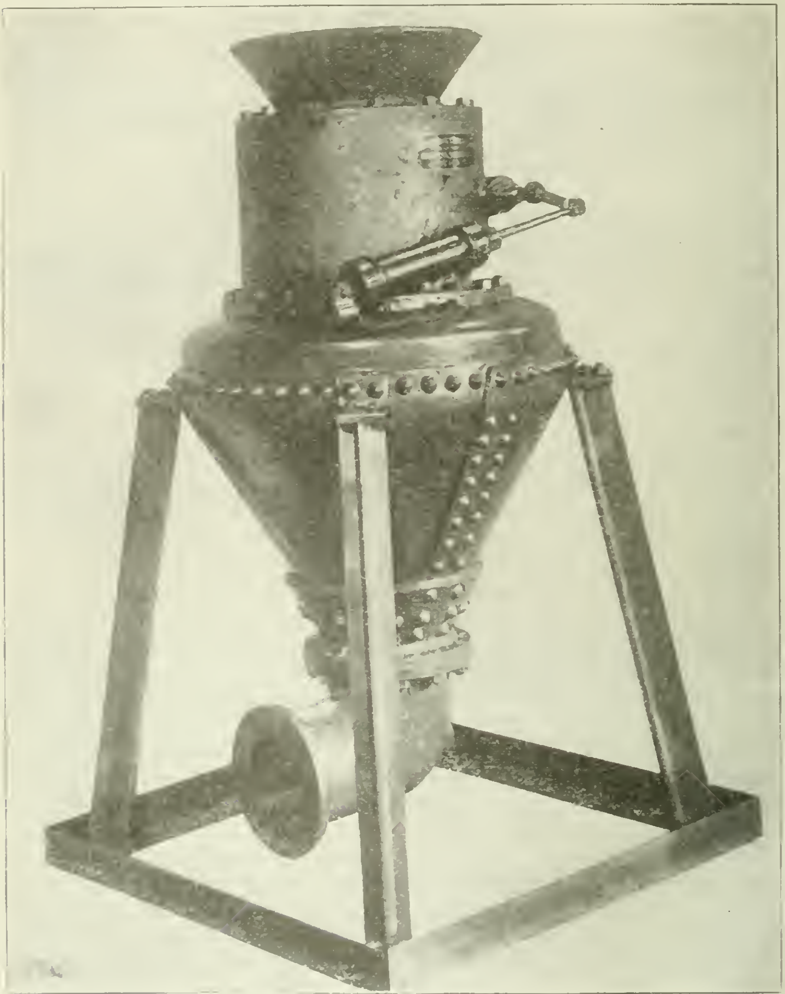
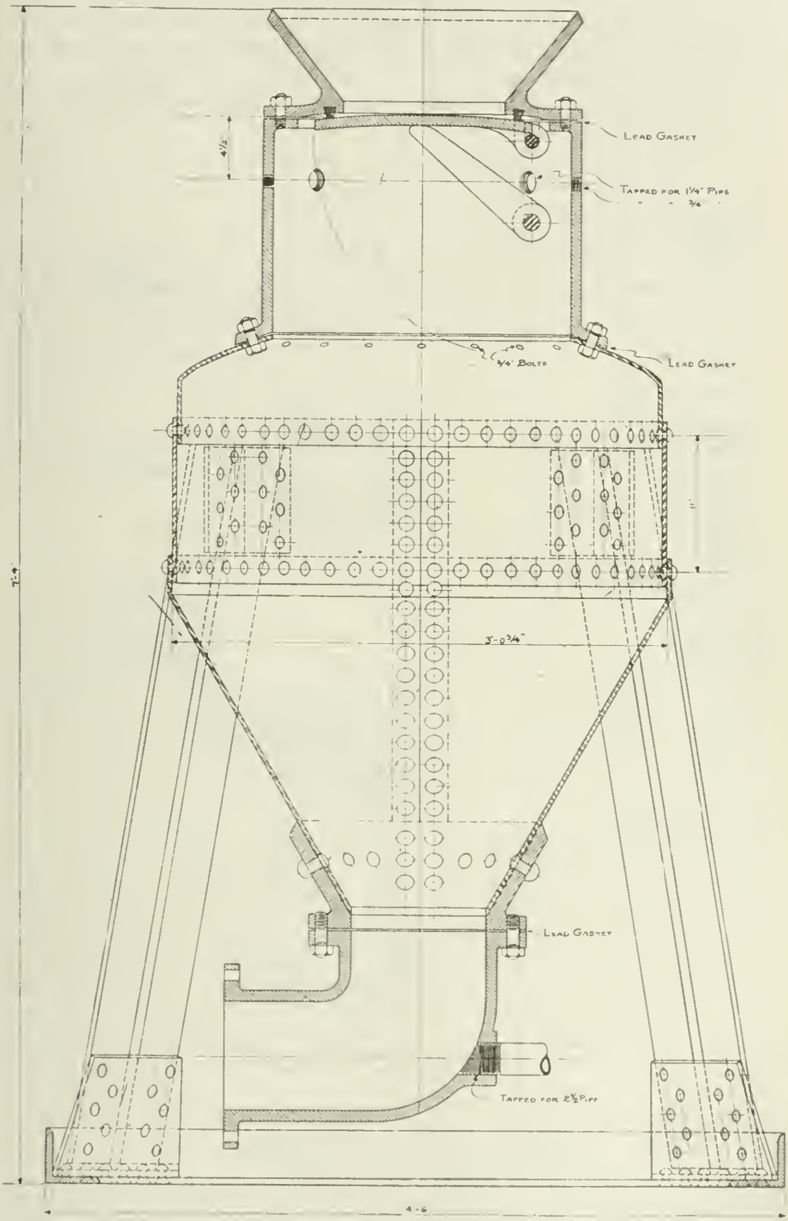
In operating, after the batch containing cement, aggregate and water is placed in the mixer, the door is closed and the main jet is located on the air supply line leading to the lower jet, and the other on the line leading to the upper jets placed above the level of the batch.



View ¼ Yard Pneumatic Mixer

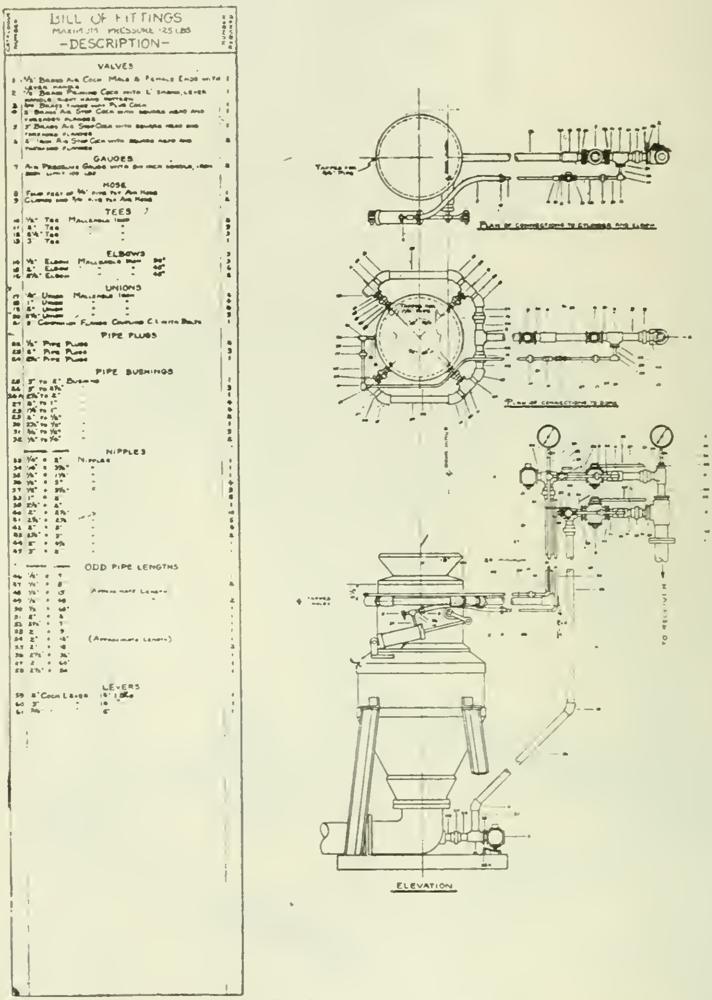
opened. This is followed by opening the valve to the upper air jets. Many operators vary this method, but the effect of this sequence of control is to start the batch forward at the bottom of the machine.



Section of ½ Yard Pneumatic Mixer

detaching successive portions of batch at the tip of the cone. The materials in the mixer flow downward in the same manner that sand flows from the upper chamber of an hour-glass, but the speed of the flow is accelerated by the air pressure.

Conveying Pipe: The conveying pipe consists of any standard



Detail of Air Pipe Arrangement

smooth steel pipe with joints made with bolted flanges or any type most easily and rapidly handled in making connections. The most rapid wear on pipe occurs at the joints where there is apt to be a slight irregularity or a shoulder. Threaded pipe is also thinner where

the threads are cut and, of course, wears through there first. For this reason we have used several types of joints and the Van Stone joint is about the best. This is out of the question now—in war times—however, on account of the cost of anything not of standard make, so we have found it cheaper to use standard pipe with bolted flanges screwed on. For making deflections of the pipe line, cast elbows are used. An ordinary cast iron elbow will last sometimes less than a day, but a case-hardened steel elbow will usually last a few weeks. The best elbow I have found to be a cast manganese, which will almost outlast the pipe itself. We have made these els in 45 degrees with a thickness of ⅝-inch on the inner curve and ⅞-inch thickness on the outer curve. This gives a weight of about 220 lbs. for an 8-inch elbow and we have, therefore, not made them longer than 45 degrees. The radius of the el is 3-ft. minimum, as a shorter radius is too sharp a turn and causes plugs in the line. Shorter radius els may be used, however, if used at the discharge end of the pipe. We have also used a split elbow of 90 degrees for 6-inch pipe. This el is split lengthwise so that the outer half of the curve which usually wears rapidly may be replaced.

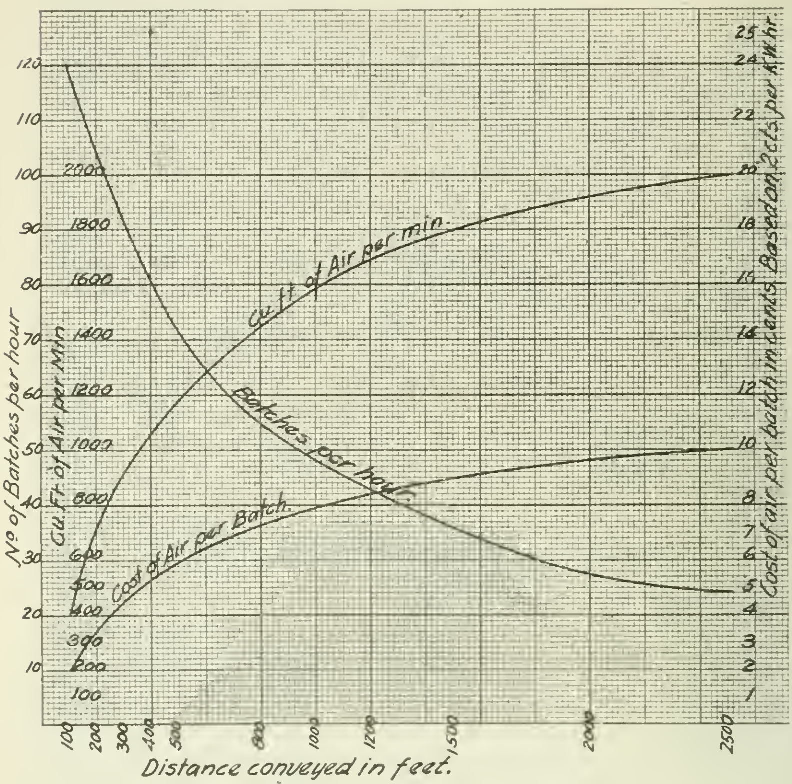
A means of deflecting or guiding the discharge of concrete in the forms consists of a series of slightly tapered pipes, fitting together like stovepipe. Two or three sections of this light pipe about three or four feet long are all that are needed in a tunnel form for diverting the discharge from one side wall to the other and for guiding the concrete discharge around points of rock projecting from the roof. Where the tunnel is very wide, however, as in a double track railroad tunnel, we have used a "Y" branch in the line, thus separating the line into two lines of pipe entering the tunnel form. A slide valve or gate is placed in the "Y" for diverting the batches through one line or the other.

Compressed Air Plant: A suitable type of compressor and the one usually employed in a straight line, one or two stage machine compressing to 80 to 125 lbs. The motive power may be steam, oil or electricity, as is most economical under the conditions prevailing. When possible, it is desirable to locate the plant near the mixer, but it is necessary to provide air storage close to the mixer, sufficient at least, to store enough air to discharge a batch of concrete at the maximum distance required. This storage should be at least 100-ft. capacity, with 30 cu. ft. capacity added for each 100 feet of pipe line. There should be additional storage at the compressor if the mixer is located a considerable distance away (for example, more than 300 ft. away).

The amount of air required to convey concrete depends upon the specific gravity of the materials, the smoothness of the pipe, the number of bends in the pipe line and their radius, the distance conveyed vertically and horizontally, and upon the pressure or velocity of the air used. For the standard size mixers the amount of air required is 2 cu. ft. of actual free air compressed to 100 lbs. per square inch per lineal foot of pipe per batch. In other words, to

convey one batch 500 ft. it will take 1,000 cu. ft. of actual free air compressed to 100 lbs.

Based upon this figure, I have drawn a curve to show the amount of air required to convey concrete at various distances. This curve is based upon practical observations on a number of jobs, and certain assumptions have also been made in order to complete the



Curve of Capacity and Air Required at Distances to 2,500 Feet

the storage tank in the time required to shoot a batch. Thus, if the figures. I have assumed in this curve certain conditions of the concrete operations as follows: twenty seconds are allowed for opening the door and charging the mixer after each batch has been discharged and the air valves closed: five seconds are taken at the length of time to convey a batch each 100 ft., and as the distance becomes greater the number of batches per hour decreases until with 2,500 ft. the number is 24, and the amount of air at this distance is 2,000 cu. ft. per minute. It should be borne in mind that if it is desired to get the maximum output possible, the capacity of the

compressor should be great enough to build up the air pressure in distance is 1,000 feet, it will require 2,000 cu. ft. of free air compressed to 100 lbs., and the time required to shoot the batch will be 50 seconds plus the time required for loading the next batch (20 seconds), or a total of 70 seconds. This requires, then, for a maximum capacity of operation, a compressor which will provide 2,000 feet of air in 70 seconds, or 1,700 feet per minute. It should be borne in mind also that we are speaking of actual air and not of compressor ratings. A 600-foot compressor will produce actually about 480 feet of free air or 80 per cent of its rating.

One of the first questions asked by the engineer is, "How is the concrete mixed?" This is explained by making a study of the conditions which affect the batch from the time it is placed in the mixer until it is delivered in place in the forms.

In loading the mixer the ingredients, cement and water are usually placed in a measuring hopper so that when the hopper is emptied into the mixer the first commingling of the ingredients takes place. This first commingling is not particularly important, as it is very slight. When the air is turned on that portion of the batch, which is at the bottom of the mixer, in front of the conveying air jet, is first to move and is instantaneously followed by portions dropping from above. As the mixer has the shape of an hour glass, the central portion of the batch in the mixer flows down first, and the portion in the sides follows in the stream from the upper part, exactly as sand flows in an hour glass. During this operation the mingling of the different ingredient parts causes the smaller ingredients to flow into the voids between the larger ingredients. As the portions of the batch drop into the lower air stream, which has a velocity of about 5,000 feet per minute, these portions are carried along in suspension much as dust is carried along in a storm, except that the particles are much closer together. Although the speed of the air jet is very high, the speed of the concrete materials is much slower. The speed of the concrete varies according to the amount of voids in the materials which permit the air to pass through. The air in passing through the voids tends to carry with it the smaller ingredients: that is, the sand tends to fill the voids between the rocks and the cement tends to fill the voids remaining, and, as the voids become filled up with the smaller ingredients passing through, the speed of the mass increases, the pressure of the air behind the mass increases with the decrease of the voids in the mass, and the speed of the mass concrete increases.

Now, in this explanation of the mixing process, I have assumed that the air velocity passing through the pipe is sufficient to keep the materials in suspension, and it is important to have a sufficient air pressure to keep the materials in suspension, because when the air velocity is reduced the materials simply roll and tumble along the bottom of the pipe. The concrete will also mix in this manner, but it is not conducive to good operation and makes a dirty pipe line, which is liable to become plugged. In shooting concrete, therefore,

it will be found that with an 8-in. pipe and with materials of the specific gravity of limestone, the pressure should not fall below 50 pounds, as the materials will then commence to drag along the pipe. Any air expended below 25 pounds is wasted when blowing concrete through an 8-in. pipe.

Examples of Work: Three general types of pneumatic installations have been developed through the requirements of different classes of work. These are (1) Central plant or scheme of locating the mixer at a central point from which the conveyor pipe

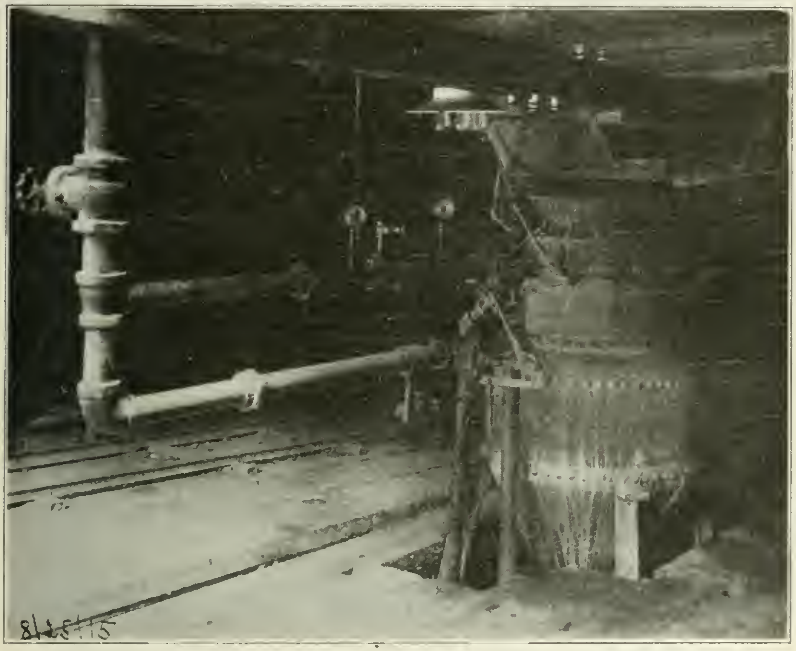
Goose-Neck, Otis Steel Company's Plant

is laid to the forms, (2) Portable plant or outfit upon which the mixer is carried and is either loaded from bins carried on the same conveyance or supplied by a belt or other loading device and (3) the scheme of loading the mixer at various points as at the bottom of manholes in shallow tunnels and supplying it with materials through a chute from the various corresponding points along the surface. The last is a form of central plant made semi-portable.

I. Central Plants: One of the jobs done under the first scheme was the construction of piers for the Otis Steel Plant at Cleveland. The mixer was located under the bins which were filled by clamshell buckets handled by a locomotive crane. From the mixer an 8-inch line was laid to the various sections of the area, giving a maximum conveying distance of 750 feet. The piers were from

12 to 18 feet in length and contained from 10 to 19 cubic yards. The gooseneck delivery end was built to elevate the concrete above and into the forms and this was moved about on rollers from one pier to another. It contained a swivel joint permitting it to be placed so as to reach four piers at one setting. The plant contained one ¼-yard mixer and was supplied with air by a motor-driven 600 cu. ft. Ingersoll-Rand compressor.

Another interesting job of this type of plant was the lowering of the West end of the Van Buren street tunnel in Chicago. This tunnel carries a double track street railway under the Chicago River

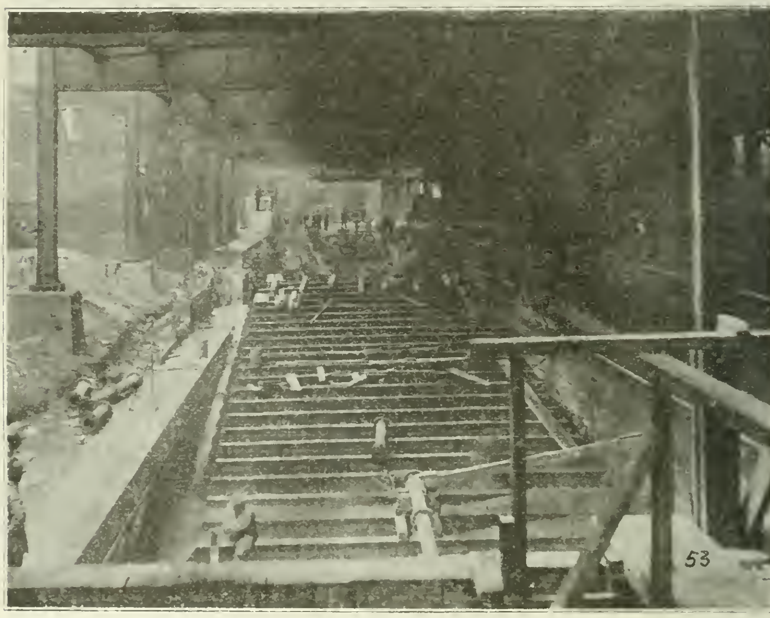


Mixer Under Bins VanBuren Street Tunnel

and under the tracks of the Union Station. The tunnel grade was lowered about 15 feet, and a new section, slightly less in width than the old tunnel, was designed. First the side walls and roof of the new tunnel were built, but instead of being carried down to their proposed depth in the first construction operation, these walls were built to the level of the old tunnel floor or invert and then the new roof was built upon them. Afterward the new side walls were extended down to the new level by underpinning. Alternate 10-ft. sections of wall were excavated and filled with concrete down to the depth of the wall, and the remaining 10-ft. sections were excavated and filled after the first sections had been completed. After the

walls were carried down to the new level, the core of earth was excavated and the concrete invert constructed, thus completing the tunnel section.

Inasmuch as the section of tunnel which was lowered was only 700 feet long, it was possible to locate the pneumatic mixer with bins above it at about half way between the ends of the work, thus making the maximum distance which it was necessary to convey concrete about 350 feet. This central point was at the old tunnel portal. Bins were located here over the mixer and the top of the bins came to the level of the street, so that materials brought in motor trucks were dumped directly into the mixer. An air receiver

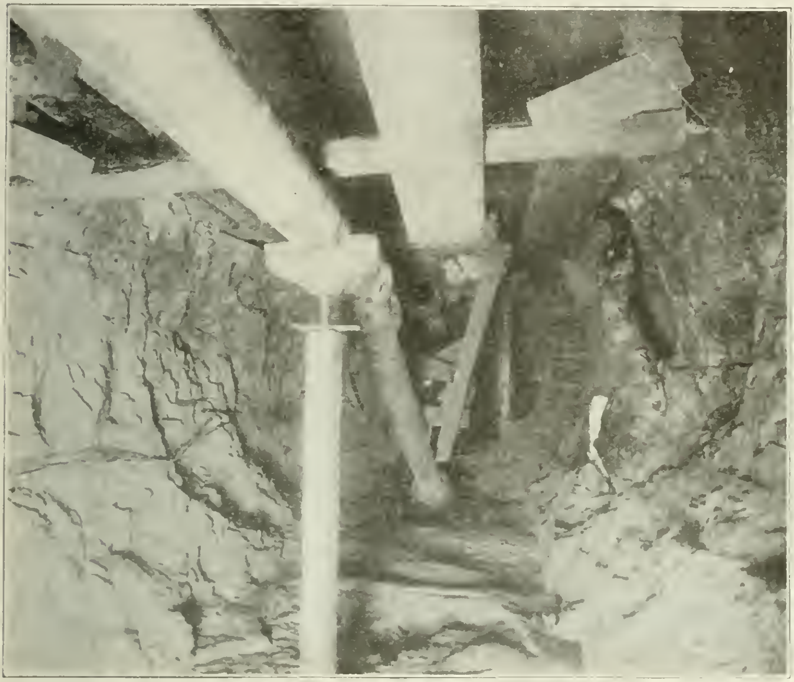


Discharge Pipe on Roof of VanBuren Street Tunnel

of about 120 cubic feet capacity was located near the mixer and air was supplied by a Sullivan angle compound motor-driven air compressor, belt connected. The compressor had a rated capacity of 628 cubic feet of free air per minute.

Another interesting piece of work was the lining of the Chain of Rocks tunnel, which is an 8-foot tunnel under the Mississippi, north of Saint Louis. The tunnel was excavated in limestone, was 2,700 feet long and 8 feet in diameter, with a 9/18-inch concrete lining. A shaft was sunk on the shore of the Mississippi 96 feet deep at a point 500 feet from the land end and 2,200 feet from the crib end in the river. The Pneumatic mixer was set at the bottom of

the shaft and a hopper for measuring the batch was built at the top of the shaft. The land section of the tunnel was first concreted. Work was begun with a line of 8-inch discharge pipe about 470 feet long, extending along the tunnel to the forms. The forms are built of structural angles and channels with wooden lagging and light sheet metal nailed to the lagging. The forms were portable and were carried on two small trucks running on a narrow gauge track placed on the invert. The forms are 36 feet long and are provided with screw jacks built on the trucks for lowering and raising and with



Discharge Pipe and Sand Bag Bulkhead, Chain of Rocks Tunnel

turnbuckles which are used to pull the wings in laterally to provide clearance when moving the forms.

The forms were first set up about 50 feet from the end of the tunnel and the pipe from the mixer was run through them to carry concrete for placing the invert. After this section of invert was placed the forms were pushed back over the completed invert and were made ready for concreting the arch. A heavy bulkhead, placed at the rear, was reinforced with sand bags. The concrete discharge pipe was laid along the tunnel from the machine to within 20 feet of the forms and here a 22½-degree elbow was inserted and then a 20-foot length of pipe was added, which brought the pipe

up to the roof of the tunnel, where another 22½-degree elbow was placed in the line, then a straight piece of pipe about 18 feet long was added, which carried the end of the pipe over the top of the form to about the middle point of its length. The front bulkhead was made by bolting a 9-inch board to the forms and then as the concrete began to fill up, sand bags were laid to complete the bulkhead and to fill up the irregularities between the 9-inch board and the rock.

The concrete in discharging from the pipe at a velocity of about 100 feet per second is discharged against the back end of the arch, where it flows down over both sides and assumes about a 30-degree angle, sloping forward. When the form is filled so that the arch is within a foot or so of the pipe, the last section of the pipe is removed so that the end of the pipe is then projecting just through the bulkhead and the balance of the section is completed. The concrete is blown in until the concrete is within a foot of the pipe and this last portion of the arch may be filled nearly full by discharging a small batch of the proper volume. The usual practice, however, is to move the forms forward until it just overlaps this little cavity.

The first 500 feet of tunnel was started April 27th and completed May 22nd. The intention at first was to run one arch every other day or three arches a week and to run invert on the intermediate days, thus allowing the arch to stand 36 hours. It was found, however, that the arch could be moved every day, so that it resulted in running four forms in four days, and the other two days were devoted to running invert, etc. On the days for running the arch the form was moved in the morning and made ready to begin concreting at 1 o'clock in the afternoon, as it was found that the arch was always completed before 5 p. m., and on one occasion the arch was run in three hours.

The compressor plant for this work was originally provided for the excavation of the tunnel and consists of one 950 cu. ft. Ingersoll-Rand straight line machine and one 678 cu. ft. Norwalk tandem compound-machine. There were three air tanks on the work, so there was an opportunity to determine by experiment how much air was required to operate the pneumatic mixer. This was a ¼ yd. machine. To determine the amount of air used all three of the tanks were first filled to 80 lbs. pressure. The compressor was then shut down and a ¼ cu. yd. batch was discharged. The combined space in the tanks was 349 cu. ft. Two of the tanks were 125 cu. ft. capacity each and one was 99 cu. ft. The second batch was discharged by using one of the large tanks and a small one and the third batch was discharged using one of the 125 cu. ft. tanks. The amount of air used calculated by reading the pressure gage after the first shot was 1.7 cu. ft. of free air per lineal foot of pipe when using the three tanks and was 1.4 cu. ft. of free air per lineal foot of pipe when using two tanks and was 1.1 cu. ft. of free air when using a single tank.

For concreting the river section the mixer was moved out under

the river to a point 1,000 feet from the end of the tunnel. Here it was placed in a hole excavated in the bottom of the tunnel so that the mixer would be low enough to permit dumping batches into it from the cars which were hauled from the shore shaft. After this work started the men soon became familiar enough with the job to handle two 36-ft. sections of tunnel in each day of eight hours. A form would be moved in the morning and completed by noon and the second form moved and completed in the afternoon. The next morning the first form would be moved after having had 20 hours to set. The first form was started at the extreme end of the tunnel, working toward the mixer, and the second form was

Portal and Bins, Diana Tunnel

started half way from the mixer to the extreme end of the tunnel, the concrete pipe passing through the first form to the second.

Another job handled by the stationary type of plant was the lining of the Diana tunnel of the Louisville and Nashville Railway, 1,520 feet in length, 29 feet wide and 25 feet high. It is in limestone and shale formation and has a lining 2 feet thick. The mixer with storage bins and measuring hopper, etc., was first placed on the South end of the tunnel. One set of Blaw traveling forms was started at the South portal and the second set was started 400 feet in the tunnel. These forms progressed away from the mixer until the first form had reached the work started by the second form and the second form had reached approximately the center of the tunnel.

Then the mixer was moved from the South end of the tunnel to the North end and the forms moved up so that the first form would start at the center of the tunnel and the second form half way between that point and the end of the tunnel. The forms then progressed toward the mixer until the tunnel was completed. One of the distinguishing details of this piece of work was the use of a "Y" connection which was used on account of the extreme width of the tunnel arch. This "Y" was placed in the delivery pipe-line as it entered the arch.

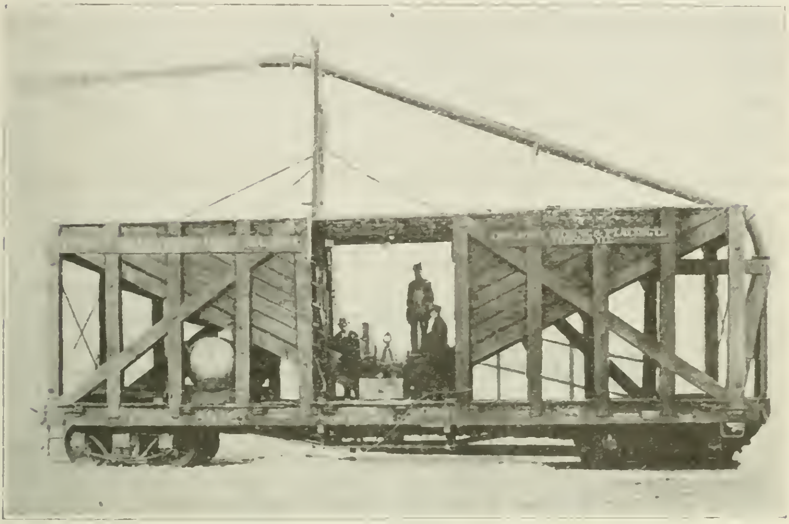
Forms and Delivery Pipe, Diana Tunnel

One leg of the "Y" led to one side of the arch and the other leg to the other side. A sliding plate with an 8-inch hole in it was used as a gate in the "Y" to switch the flow of concrete from one branch to the other. This gate is moved back and forth by the use of a small sledgehammer.

The two 8-inch pipes passing over the crown of the arch reach about 20 feet or midway into the forms, and at that point they turn through 90-degree elbows to each side wall. At the end of the elbow a 9-ft. length of 8-in. hose was suspended. While the concreting was going on, two men with ropes attached to the end of this hose stationed themselves at the ends of the form so that they could pull the hose forward and back and deposit the concrete evenly along the side wall. After sufficient concrete had been poured to bring the side wall up from 2 to 6 feet, depending on the thickness, the concrete was diverted through the other side of the "Y" and

deposited in the opposite side wall to balance the weight against the forms.

When the concrete reached a point too high for the use of the hose, this was detached while the concreting was going on at the

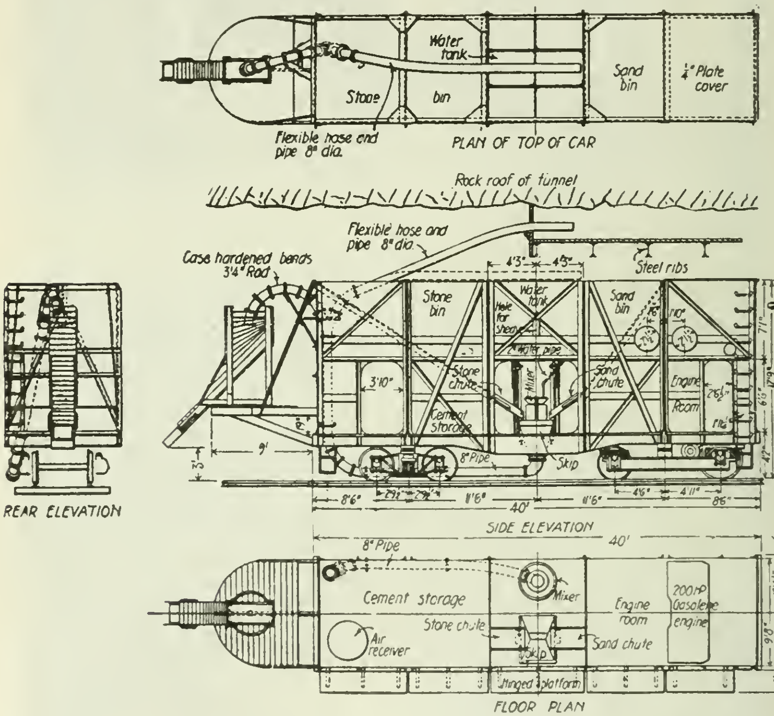


View C. B. & Q. Car, Arminto Tunnel

Discharge Pipe and Forms, Arminto Tunnel

other side. Concrete was then discharged directly from the elbow until the space was filled close to the end of the elbow. During this period of the pouring, the concrete was leveled by means of concrete rakes. This brought the level of the concrete up to a point nearly level with the top of the barrel on the arch form, and left remaining to be filled a space approximately 10 ft. wide and from zero at the sides to 18 in. in height over the crown. The 90-degree elbows were then removed from the ends of the pipe and a short hose was attached to one of the 8-in. pipes, the other pipe having been removed. Concrete was then shot against the rear and built up to the end of the hose, after which this hose was removed and the concrete shot straight ahead from the end of the pipe until the key was completed.

At the North end of the tunnel the temporary timbering was removed as concreting progressed. Considerable breakage in the



Detail C. C. & O. Car, Dante Tunnel

roof left cavities of various depths which it was necessary to fill either with concrete or with some variety of packing. Where packing was used it was placed with the pneumatic machine. The packing material consisted of a mixture of 75 per cent limestone screen-

ings and 25 per cent sand. This was blown in, filling the cavity completely and packing it tightly so that the weight or any pressure from rock settlement was evenly distributed over the barrel of the arch through the packing.

The compressor plant consisted of two Ingersoll-Rand steam-driven compressors, which delivered about 960 feet of free air per minute at the mixing plant.

At the beginning of the work the engineers permitted the moving of the forms after six days, but after a time this period was reduced to four days. In all there were 41 form sections, each of approximately 35 feet and containing about 250 cu. yd. in each section. The longest distance which concrete was transported was 925 feet and the average distance was about 400 feet. The average time required to concrete one 35-ft. section was approximately 24 hours, although some forms were filled in 15 hours. The number of men required to mix and place the concrete was 13, including three men in the bins, one operating the gate levers, one to level off the measuring hopper containing the batch, one man on cement, one mixer operator, one man on the conveyor pipe, one attending to the bulkheads and one foreman and four men helping in the forms. A gang of ten men was employed constructing footings and moving and setting the forms.

The Mile Rock tunnel in San Francisco at the time it was built was distinguished because they carried the concrete there to a distance of about 2,900 feet, using a 6-in. pipe. It was a sewer tunnel built in soft ground and the forms followed the heading closely, the pipe passing through the forms up to the arch and back over the crown, as is always necessary when the forms are moving away from the mixer.

On this job a two-stage Ingersoll-Rand compressor was used with a capacity of 1,100 feet of free air per minute. The mixer was ¼ yd. capacity. A rubber hose about 4 feet long was used on the end of the pipe for distributing the concrete. We do not now advocate the use of a rubber hose for this purpose, as it is expensive and has a very short life. We use instead the light flexible pipe previously described.

The Twin Peaks Tunnel, a double track street car tunnel in San Francisco, is noted particularly for the long distance the concrete was conveyed, the distance being at its maximum about 4,900 feet. An 8-inch pipe in a 16-cu. ft. mixer was used.

Another example of a central plant layout is the construction of the Montreal Reservoir Walls. A half-yard mixer was located under bins and the pipe extended along the ground to the walls, which were 37 feet high, then up and along the top of the wall forms to the point of deposit. The greatest distance the cement was conveyed was 600 feet, including the 37-ft. rise which occurred at about 100 feet from the mixer.

The gang operating the plant comprised about eight men, including the foreman, distributed as follows: Two carrying cement

to chute and dumping sacks, 2 operating levers admitting materials to measuring hopper, 1 operating water-tank valve and assisting mixer-operator, 1 mixer-operator at air valves and admitting materials to mixer, 1 to 4 at discharge end spreading concrete in wide forms, and 1 foreman. The spreading squad shifted the discharge pipe when necessary.

The average rate of pouring on the wall was 100 yards per shift, which usually filled all available forms. On the dam progress was much faster because of larger sections, the average rate being 250 yards per day. High rates of pouring were attained, but could not be maintained long owing to lack of material, necessity for changing pipe, or the fact that too much liquid concrete could not be poured into a form at once. On most days the rate of pouring varied from 30 to 50 yards per hour.

During the time this work was carried on there were days when the temperature was down to zero, but no difficulty was experienced on this account. The water and sand were heated and the operator's platform inclosed. As only a few seconds were required for transit, the concrete went into the forms hot, and in the large masses with heavy forms there was no chance of freezing.

II. Portable Plants: Another type of plant used is the portable plant, of which a number have been used. The first portable plant was built for the Chicago, Burlington and Quincy Railroad. It consists of a Pneumatic Mixer and Conveyor mounted on a 40-ft. flat car equipped with bins with capacity of 26 yds. of bank-run gravel. The cement was stored in bags under one of the bins. The bins discharged by gravity toward the center of the car into a measuring hopper. This measuring hopper was arranged to tilt and discharge into the mixer and in tilting it had to be lifted about 2 feet. This was done by means of a cable attached to a 6-inch air cylinder containing a piston about 6 feet long. The 8-in. delivery pipe led from the mixer into the car and up at the end of the car to the crown of the arch where it turned into the crown through a 90-degree elbow. This elbow was suspended from the roof of the tunnel by means of block and tackle so that the lower end of it could be disconnected from the pipe on the car and the elbow was then left hanging in this position while the car was pulled out of the tunnel to get another supply of concrete materials.

Air was supplied from a compressor at the mouth of a tunnel through a 4-inch pipe laid along the side of the track with an air hose at the end for connection to the air receiver on the car

A plant similar to this, but more complete in detail, was built for the Carolina, Clinchfield and Ohio Railroad for the lining of the Sandy Ridge tunnel near Dante, Va.

This tunnel is a single track railroad tunnel 7,804 feet long. The principal features of the car are as follows: Forty feet long, 10 feet 4½ inches wide near the braces and 17 feet 9 inches from the top of the rail to the top of the car.

As shown in the accompanying drawing and photographs, a

central chamber open on the sides, 8½ feet long, 9 feet 8 inches wide and 10 feet 3 inches high, in which on one side is located the pneumatic concrete mixer and on the other side the charging skip. Over this chamber is a watertank of 1,850 gallons capacity, which furnishes water for the concrete and is also connected with the cooling system for the gasoline engine. On one end of the car, facing the central chamber, is a stone bin of 30 cu. yds. capacity. Each bin has a chute 20 inches wide leading to the charging skip and each chute is controlled by an under-cut gate. Under the stone bin is a space occupied by a 96-cu. ft. receiver, standing vertically, and the storage of the cement in bags.

Under the sand bin is the gasoline engine and its auxiliary equipment completely housed from water and dust. The charging skip in its lower position stands with its top rim about 1 ft. 3 in. above the floor and travels on inclined guide rail to its upper position over the mixer, being hoisted by a compressed air cylinder 9¼ in. in diameter. The gate of the skip works automatically by means of a guide rail. The mixer is for a two-bag batch (0.4 cu. yd.) and has an 8-in. outlet pipe at the bottom running horizontally and curving to the outside of the rear truck and thence vertically to near the top of the car, where it branches by means of a wye into two lines, one a 180-degree bend to the rear for "shooting" into foundations and sidewalks, and the other going to the roof for "shooting" into the arch. The wye is a special device with a sliding plate controlling the movement of material into either arm. The arrangement of the pipe, traveling with the car and being in position at all times for "shooting" concrete, results in a material saving of time and expense.

Along one side of the car, level with the main floors, is a folding platform 2 ft. wide used by the men carrying cement and to gain access to the engine room. During the ordinary work of the car this platform remains down. The arrangement is compact and arranged with a view to save manual labor. One man controls the hoisting of the skip, the injection of water and the mixing and discharge of the batch. One man is placed at each chute and two men carry, open and empty, the cement bags.

The gasoline engine is of the six-cylinder, four-cycle tee-head type and is rated 200 h. p. at 350 r. p. m. It can be throttled to 125 r. p. m. The motor and its frame constitute one of the trucks of the car. The cylinders stand in a row at right angles to the track and the whole construction is compact but accessible. The engine is started by admitting compressed air into three cylinders, then the explosion of the gasoline takes place in the other cylinders and continues the motion. The transmission is by means of a Morse chain on the driven axle (one only being used) and the control is through a friction clutch of special design.

The loading and storage trestle is of special design and so arranged that the concrete car goes under it and receives crusher-run stone, sand, bag cement and water by gravity. The sand and stone is drawn from overhead bins by means of under-cut gates. Cement

is conveyed into the car by a chute. The trestle has a track over its deck upon which stone and sand in hopper cars are stored or unloaded into the bins below. There is a continuous row of 27 bins with an aggregate capacity of 324 cu. yds. and a total length of 162 feet, and five loaded cars can be stored over these bins to give an additional storage capacity of 200 cu. yds. The general arrangement is shown in the track layout and in two of the photographs.

The compressor plant was exceptional for a temporary outfit. To save money on foundations and at the same time to increase the space, the floor level of the boilers and compressors was fixed 4½ ft. above sub-grade, the concrete foundations and walls were built up to this height and the cellular space underneath was utilized for water tanks and ash pit. The building was built of 1-in. boards covered with tar paper. The arrangement chosen permitted coal to be dumped from cars on the trestle to a pile in front of the boilers. There were two boilers, both locomotive type, one new, one of 150 h. p., and one old one of 70 h. p. The piping connections were such that either one could be cut in or out of service for cleaning or repairs. Two compressors are installed, but an extra foundation for another unit was provided, for reasons mentioned elsewhere. The compressors were alike and of the Ingersoll-Rand F. R. I. Rogler valve class, a high speed, single stage type with a steam cylinder 12 in. by 12 in., an air cylinder 12 in. by 14 in., a piston displacement at 250 r. p. m. equal to 528 cu. ft., an actual output of about 375 cu. ft. of free air per minute each. This worked under 125 lb. steam pressure and compressed air to 115 lb. They were cooled by water brought by gravity from the mouth of an old coal mine. From the compressors a 6-in. pipe leads to a 150-cu. ft. air receiver, from which a 4-in. pipe line led on a steady 0.5 per cent down grade entirely through the tunnel. At the lower end was a pet cock to draw off any water. In order to provide for expansion and contraction, the pipe line was laid alternately on the east and west sides of the track in lengths of about 1,000 ft., connected by curves of 2 ft. radius. The bottom of the pipe was at the level of the bottom of the ties and 1 ft. out from their end. About every 100 feet a long radius tee was placed and about 20 mine cocks of 4-in. size were provided; these could be shifted to the various tees as the progress of the work demanded. From the mine cock a 3-in. hose 60 ft. long connects with the 96-cu. ft. air receiver on the car, which can thus be connected to the 4-in. pipe line from any position in the tunnel.

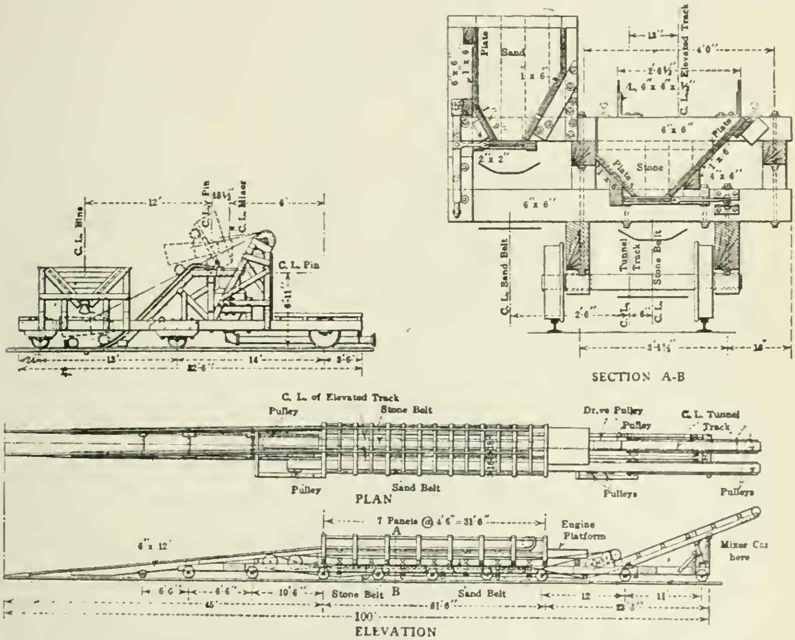
Several runs of 180 cu. yds. per day and one run of 201 cu. yds. were made. The work consisted of putting in the foundation and the initial lift of bench wall 4 ft. 4 in. high, which involved moving the car more than was necessary when "shooting" into the arch form.

Another feature of this plant is the short pipe through which the charge moved. The pipe is 41 ft. long to the chute on the front of the car and the mixture is good, using a ½-yard machine. The

difficult problem on a car like this is to design the plant so as to charge the mixer fast enough to work to its capacity. The mixer can shoot a batch every fifteen seconds if enough air is furnished and the charges can be placed in the machine fast enough. The time records on the work of this car are as follows:

Aug. 17, 1915, 423 batches in 381 min., average 54.0 sec. per batch.
Aug. 18, 1915, 323 batches in 302 min., average 56.1 sec. per batch.
Aug. 19, 1915, 448 batches in 340 min., average 45.5 sec. per batch.
Aug. 20, 1915, 325 batches in 250 min., average 46.1 sec. per batch.
Aug. 21, 1915, 309 batches in 309 min., average 54.3 sec. per batch.

The variation is due to the condition of the material whether wet or dry, which affects the rapidity with which it flows in the chutes and skip. It is believed that the operation can be speeded up to an average of about 35 to 40 sec. per batch with dry material.



CARS RAN UP ON ELEVATED TRACK SIDE DUMP DISCHARGING SAND AND BOTTOM DUMP STONE INTO BINS FROM WHICH TWO CONVEYORS TOOK MATERIAL TO HOPPER OR MIXER; CAR WHICH LOADED CHARGING SKIP

Plant Layout, Montreal Tunnel, Canadian Northern Railway

One should observe that the door of the skip automatically opens as the skip reaches the position and closes as it is lowered away; also that the door serves as a chute while open and that the side slopes are steep and unbroken, so that the skip clears quickly. The material when damp has a decided tendency to arch either vertically or horizontally, and frequently this arch must be broken

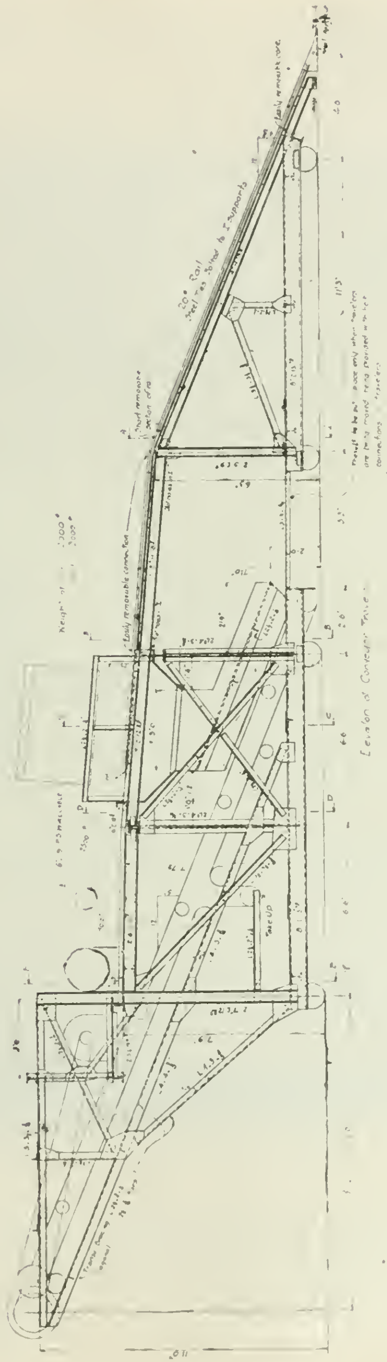
by hand. The hoisting of the skip, the placing of the water and the discharge of the batch are all controlled by one operator. The inside of the car was lighted by carbide lights and the outside work by hand torches and carbide lights.

An interesting portable plant was used on the Mount Royal tunnel on the Canadian Northern Railroad at Montreal. This plant placed about 37,000 yards of concrete in eight months with seven sets of forms.

The Mount Royal tunnel was a double track railroad tunnel 28 ft. 6 in. wide and 19½ ft. high from top of rail. The concrete was built above the spring line only for a part of the work. The materials for concrete were brought in the tunnel in cars which ran up an inclined portable track. In front of the mixer-car was a car about 18 ft. long which carried an air receiver of 158 cu. ft. capacity and also supported the discharge pipe. At the entrance upper end of the discharge pipe where it turned into the forms a swivel joint was used which aided in distributing concrete from one side of the arch to the other. This plant was designed for a 3-ft. gauge track and the height was governed by the head room under the forms which was about 12 ft. from the top of the rail. The material trains were run up this inclined track to the top of the conveyor car. The stone cars were center-dump and the sand cars side-dump and discharged into small boots with sliding gates from which the material was fed to a pair of belt conveyors. These conveyors carried the stone and sand to the small bins and the mixer cars. Cement was unloaded and stored on the small platforms above the ends of the belt conveyors and dumped through the small chute into the shuttle car. This plant put in 37,000 cu. yds. of concrete in 8 months with 7 sets of forms.

Another plant somewhat similar to the foregoing, but less complicated, was used in the Wilson Avenue tunnel, Chicago. The tunnel is 8 miles long and 12 ft. in finished diameter for 7 miles of its length, and 13 ft. in finished diameter for 1 mile of its length at the lake end. It is located in solid limestone rock about 150 ft. below datum and has a monolithic concrete lining 1 foot thick. The outer end of the tunnel is at the new crib in Lake Michigan, 3 miles from the shore at the foot of Wilson Avenue.

A pneumatic mixer was mounted on wheels together with air supply tanks and a measuring hopper located above it. In addition a belt conveyor outfit, also mounted on wheels, was used to convey the rock from under the screen to the measuring hopper over the mixer. Upon the frame work which held this belt conveyor an electric winch was mounted for hauling 1 cu. yd. cars of mine-run up the incline, to be dumped over a flat screen with 4½-in. holes. The rock which passed through the holes fell onto the belt conveyor and was carried up to the measuring hopper. The rejections passed over the screen and fell into an iron plate laid on the floor and were shoveled from this plate into the car to be hauled out of the tunnel. It occupied only one track in the tunnel, so that the other track was

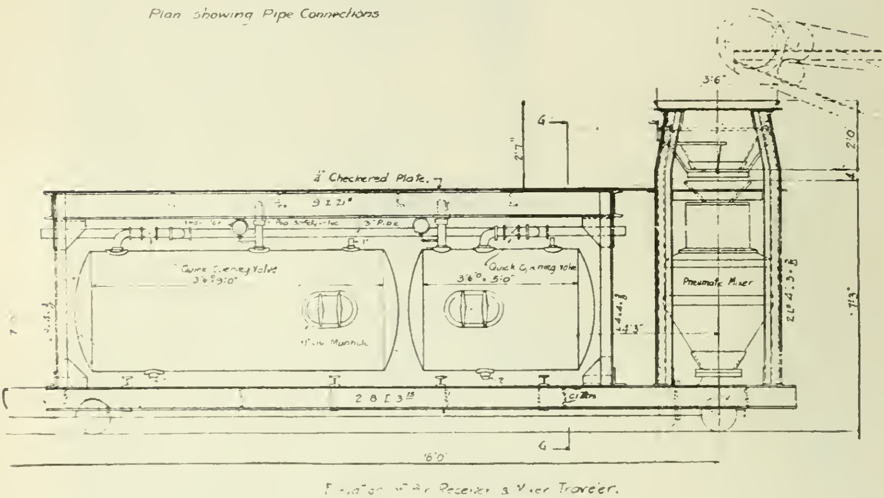


Conveyor Traveler, Wilson Avenue Tunnel

never obstructed except by the car which received the rejected rock and this car pushed to the shaft every time a muck train passed through, and an empty car was placed in its stead.

The general plan for proceeding with the concrete work involved the pneumatic mixing plant, as described, and two Blaw traveling steel forms. One of these forms was about 500 ft. away. The 8-in. pipe for conveying the concrete from the mixer to the forms was laid along the side of the tunnel through the first form to the second one, and there it was directed up a 45-degree angle and into the top of the form as shown in the view. When this form was filled with concrete, the pipe was disconnected and arranged for filling the other form, and as the concrete set, the forms were moved alternately toward the mixer, until about 1,000 ft. of tunnel was completed. The mixer was then moved 1,000 ft. farther and the same cycle of operation was repeated.

The first pneumatic outfit was started working east from the



Air Receiver and Mixer Traveler, Wilson Avenue Tunnel

shore shaft in December, 1915. At first a distance of 500 ft. was planned for conveying the concrete, but as this cycle was completed and the mixer moved to the next position, the distance was increased until experience seemed to determine about 1,000 ft. as the proper length of the cycle. The heading at this shaft was about 1 mile ahead of the mixing plant, when the concrete work was started. With two 30-ft. forms the progress of the concrete work was about two and one-half to three times the progress of the excavation work and its machine, therefore, caught up with the heading in about six months and was temporarily closed down until the heading was farther advanced.

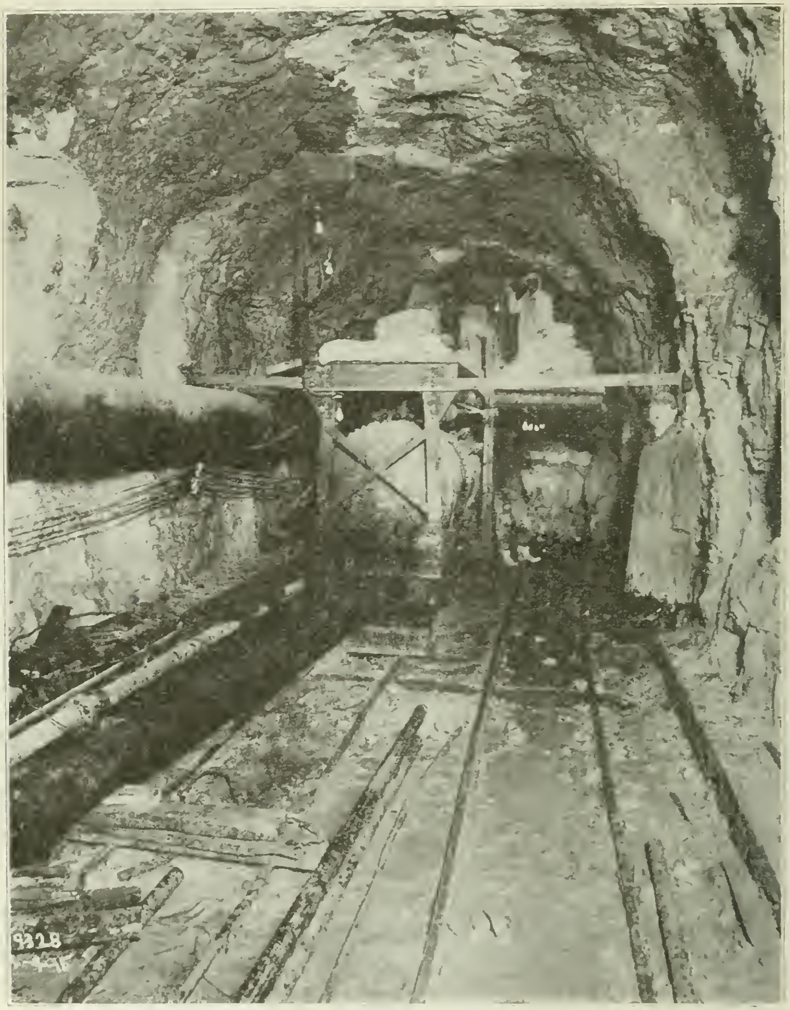
In the meantime, the heading from the Lincoln shaft was holed

through so that the rock could be hauled from the heading east of the shore shaft to be used for the concreting plant which had been started at Lincoln avenue shaft in March, 1916. Accordingly, the concrete gangs from the two machines were organized into one

Incline for Aggregate, Wilson Avenue Tunnel

gang, and one of the forms from the machine in the east heading was taken and set up for the Lincoln machine, thus making three forms follow the Lincoln avenue machine and only one form to the shore shaft machine. This arrangement made it possible for only

one gang to operate the two mixers alternately, so that, working three shifts, they were able to fix the three forms at Lincoln avenue and one form at the shore shaft, keeping the concrete work going constantly on one of the two machines. As there were four forms

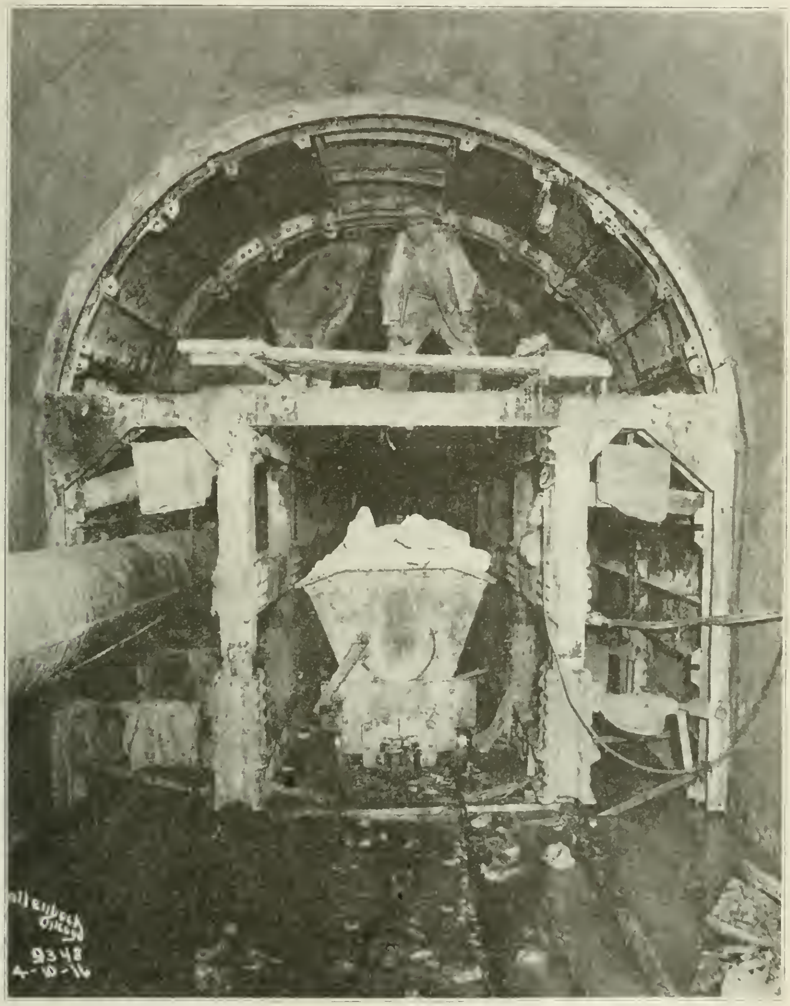


Mixer Car Platform and Air Receivers, Wilson Avenue Tunnel

in use, there was no delay caused by waiting for the concrete to set or waiting for the forms to be used. Each shift the concrete gang found a form moved and the pipe connected up ready to start the concrete work. Each concrete gang completed one form and changed

the pipe ready to start the next shift. There was a form-moving extra gang which worked one shift, moving the forms and placing the sand-bag bulkhead at the forward end.

The machine at Lawndale was started in April, 1915, and the



Rear End of Forms and Ventilator Pipe, Wilson Avenue Tunnel

one at Mayfair shortly afterward. Both of these machines used rock from the heading east of the Lawndale shaft as the tunnel had been previously holed through between the Lawndale and Mayfair shafts.

One of the new features of placing the concrete at the Lawndale shaft was the use of the pneumatic mixer for placing the concrete in the footing wall. This footing wall is usually built by hand in advance of the regular concrete work and is a wall about 1 foot high used as a guide for the forms to follow. In placing this at the Lawndale shaft the concrete was first delivered to the Blaw forms by the pneumatic mixers in the regular manner. But a key-plate was left out of the steel forms and a chute was placed in it, operating so that the concrete being placed by the pneumatic method would overflow through the chute into the car placed beneath the forms under the chute. The car then carried the concrete ahead and dumped it into the forms for the footing wall. In this way the footing wall was placed about three times as fast as it could have been placed by hand.

The number of men required for the operation of the concrete work was as follows:

Screening Rock from Heading—

- 3 men pushing up cars to incline, hooking on cable, dumping same on screen and pushing back empty cars to make train bound for heading.
- 1 man operating motor hoist for pulling cars up incline and operating belt conveyor for carrying screened rock to hopper over mixer.
- 2 men shoveling rejections from screen into cars to be hauled out of tunnel.

Cement Delivery—

- 2 men unloading cars of cement and storing same on platform above air tanks adjacent to mixer hopper.

Mixing and Placing Concrete—

- 3 men operating hopper over mixer, feeding cement, water and screen run rock.
- 1 man operating mixer, air valves.
- 1 man at end of pipe in concrete form.

When there was sufficient rock on hand for continuous concreting, the forms were filled very rapidly, one form having been filled in one hour and forty minutes. The forms contained from 50 to 70 yards of concrete, depending upon the excavating section. During January, 1917, one machine at Lincoln avenue placed 2,707 lin. ft. of tunnel lining.

The progress of the work from the beginning of concreting operation is shown in Table I.

Table I—Monthly Progress of Concreting:

Month		Yardage Placed	No. of Mixers
December,	1915	1,400	1
January,	1916	2,196	1
February,	1916	2,300	1
March,	1916	2,508	1

Month		Yardage Placed	No. of Mixers
April,	1916	5,911	3
May,	1916	2,006	1
June,	1916	2,669	2
July,	1916	2,953	2
August,	1916	330	1
September,	1916	2,933	2
October,	1916	3,720	2
November,	1916	1,352	1
December,	1916	8,725	3
January,	1917	11,355	3
February,	1917	8,502	2
March,	1917	6,311	2
April,	1917	3,064	2
May,	1917	4,213	2
June,	1917	799	1
July,	1917	1,081	1
August,	1917	3,135	2
September,	1917	2,336	2
October,	1917	1,720	1
November,	1917	2,628	2
December,	1917	4,578 / 1,839	3
January,	1918	463	1

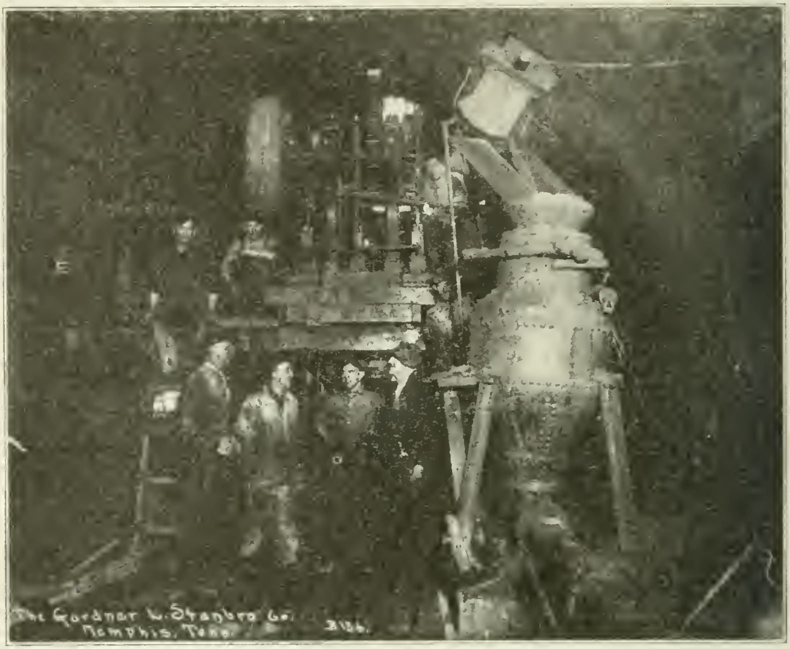
The rate at which the mixer operates cannot be figured from the data in Table 1. Working between 16 and 24 hours a day, one machine at the Lincoln shaft put in 2,900 lin. ft. of tunnel in a month and the yardage of the lining runs 2 cu. yds. per lineal foot. The ultimate capacity of the mixer is 60 cu. yds. per hour.

It should be noted that the Wilson avenue tunnel is the first tunnel in which the concrete work was carried on simultaneously with the mining and using the mine-run rock excavated from the heading for the concrete work. The use of the pneumatic method made this possible and saved over one year in constructing the tunnel.

Now we come to the third type of plant, which is really a stationary plant made semiportable and is used in shallow tunnels where materials for concrete can be dropped through from the surface directly under the mixer. Such a plant was used on the Mill Creek Sewer tunnel in Saint Louis—a 16-ft. tunnel about three miles long. The forms used were Blaw steel traveling forms in 40-ft. sections. On one contract of the work the concreting extended from July 19th to December 9th, requiring 1,928 working hours for concreting and 163 forms 40 ft. long were concreted. This work involved the handling of 18,000 cu. yds. of concrete and extended 6,261 lineal feet. The mixer was set up at the bottom of manholes at eight different points and the time required for the set-ups of the mixer being sub-

tracted from the total shift time to arrive at the above number of hours of placing. Eighty-nine cubic yards were placed per 10 hours of steady shooting and 73 cu. yds. per 10 hours working shift, total time. The best work was done when 737 feet of tunnel was lined in thirteen 10-hour shifts, making a record of 144 cu. yds. placed per shift of total time. Four sets of forms were used.

On another contract in this tunnel the best performance was the placing of 640 feet of lining in 127 hours of actual operation. In September 1,880 lineal feet of lining was placed in forty-six 10-hour shifts of which 680 feet were placed in 13 consecutive shifts, or one week. In October 1,753 feet were lined in 46 shifts, which perform-



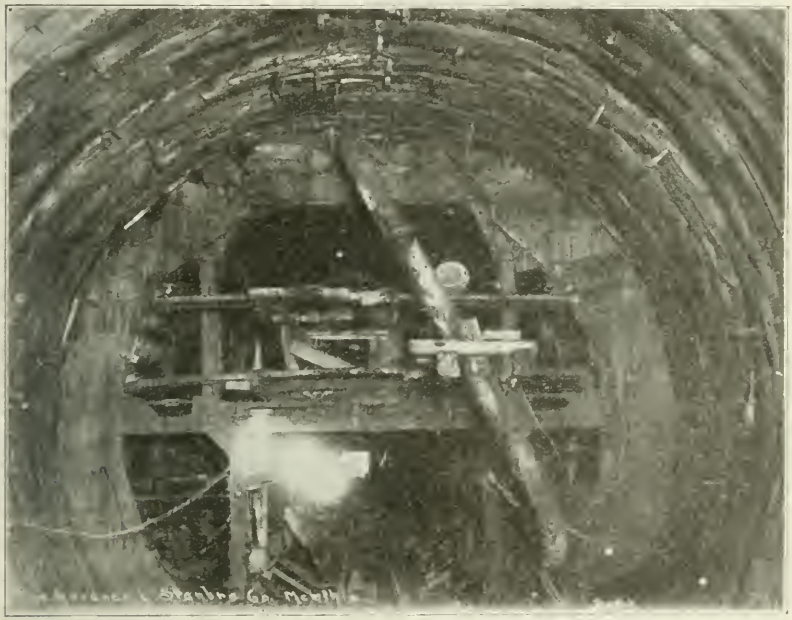
Mixer and End of Material Chute, Memphis Tunnel

ance is noteworthy because of the fact that the stretch contained two sharp curves.

Another interesting tunnel which was handled with this type of plant are the two 16-ft. circular tunnels at Memphis, built in soft ground. These were very difficult tunnels and were excavated with shields. The concrete work followed the shields as closely as possible. Both of the tunnels were excavated in air pressure for part of the work. On one of them the pneumatic mixer was located outside of the track and the discharge pipe was built through the lock

and carried through the tunnel to the forms at the heading. At the end of the discharge pipe and the top of the form a flap valve was placed so that when the mixer was blowing the valve would lift and when the air was shut off it would close by its own weight and the air pressure within the tunnel held in place. This was not quite satisfactory, however, as the flap valve would occasionally not seat itself, due to particles of concrete, so that temporarily a man was posted there with a wooden paddle to place over the end of the pipe as soon as the discharge ceased.

On the other Memphis job the mixer was located inside the air pressure section and a drop pipe led to it from the surface. At the



Discharge Pipe, Memphis Tunnel

top of this drop pipe a material lock was placed so that each batch was locked into the drop pipe in this manner.

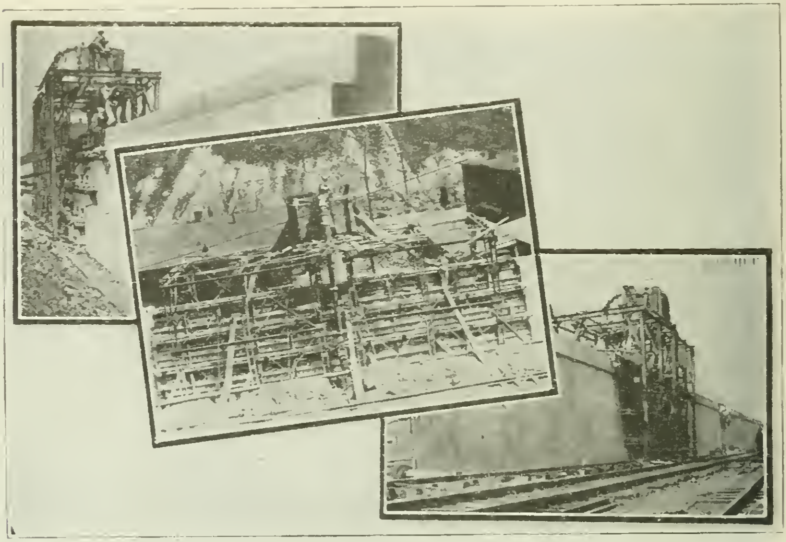
The accompanying view of wall work on the Baltimore & Ohio Railroad shows the traveling steel forms with a hopper mounted above. The pneumatic delivery pipe discharges into the hopper and the concrete flows from the hopper by gravity into the forms.

DISCUSSION.

Mr. G. A. Haggender, M. W. S. E.: The C., B. & Q. used this mixer on one tunnel and we found one of the first troubles we had was that the air compressor was not of sufficient capacity. We

averaged a batch in fifty seconds instead of forty seconds, as we should have done. We also found that the cold weather reduced the capacity; we were working at an altitude of about six thousand feet. An ample air supply must be provided, a little larger, if necessary, instead of smaller. We found we had to have large reservoirs at the mixer near the tunnel, and we also had to insulate the air pipe during the cold weather.

Another improvement has been made by having separate gravel cars. Every time we finished the gravel in the car we had to disconnect and run back to the entrance of the tunnel to load up. By having a separate car we could have switched out and put a load



Views of B. & O. Track Elevation, Pittsburgh

right in, and we would have saved time and cut down the expense. The car should be built to have a cement car on one end of the mixer car, taking the cement directly from the car instead of rehandling it, taking it along the platform along the side of the car. These are points we found after experience on that one job.

Can you tell us the number of lineal feet of concreting you can do in a month? The maximum in our railroad tunnel was 175 feet a month.

Mr. Kirkland: In the Wilson Avenue tunnel they had the best opportunity for making records. That job was eight miles long. There were four outfits; one starting at each shaft and working eastward, doing its two miles of work. The first outfit started at the shore shaft and worked eastward toward the heading. The heading was in about one mile when the concrete work was started. In about

a month or so the mixer caught up with the heading and had to be shut down. At that time another mixer was started from the next shaft west and the gang operated that mixer for a short time and then the work was arranged so that one crew could operate both mixers alternately. With each of the two mixers were originally two thirty-foot forms. One of the forms under the lake was moved to the west mixer, so that mixer had three forms following it, while the mixer under the lake had one form. The mixer under the lake was following close to the heading and the mixer west had no obstructions, as that part of the tunnel was holed through and they were enabled to work two shifts continuously on concrete work, while one shift was used for moving the forms. When the gang could not work on that mixer they would shift over to the one under the lake. In one month during January of last year, they concreted 2,707 feet of tunnel with one machine. That is the best record that has been made.

In that tunnel they at first tried to see how long it was necessary for the forms to remain in place, and it was tried out to the limit. Forms were removed in six or seven hours; in some cases so early that the roof came down with the forms, but finally a good average was found and the forms were left in place for eleven hours. The radius of the arch was 5 ft. 8 in., and the concrete was one foot thick.

In this tunnel the forms moved toward the mixer. They were started about eleven hundred feet away from the mixer and progressed toward the mixer until within about seventy-five feet. Then the mixer moved back for another cycle.

Mr. W. M. Kinney, m. w. s. e.: In experiments with cement in a bin some thirty feet high we find that once a cone is formed we get all the material from the top in first, rather than the material from the bottom. We get first the cut right through the full thirty feet, and then it begins to fall in from the top. We then get a much larger percentage of the top than from any other point.

Mr. J. H. Libberton, m. w. s. e.: One of our tests to determine the completeness of the mix was to add coloring matter to the concrete, discharge it a small distance away and examine to determine how thoroughly the coloring matter had been mixed in the concrete.

Mr. Wm. Artingstall, m. w. s. e.: Another way is to take a bunch of colored rags, both long and short ones, and discharge them and notice how they come out. You will find they are very much mixed up. There seems to be a kind of twisting action in the mixer, due to the pressure, so that the center of the mixture soon comes to the outside and covers the rim with concrete, while the material on the outside rim then, in fact, becomes the center of the mass.

Mr. Kirkland: In one case we tested with different colored sand and brick chips, and got a uniform coloring at the discharge.

When the concrete comes down through the inverted cone the center of it comes first and peels the other materials away from the sides so that you are getting part cement, part of the sand layer

and part of the rock layer simultaneously through the pipe. That is, assuming you put the materials all in separate layers. In a pneumatic mixer the air immediately begins to force the smaller stuff into the voids and you get quite a different combination.

It is not necessary to mix the materials at all before putting them in the mixer. We have tried all sorts of schemes to see just how it affected the mixture to partially mix it or put the sand and stone and cement in every possible sequence, and we cannot tell the difference in the mixture when the concrete comes out of the discharge pipe. We have conveyed concrete as far as 4,900 feet, and I think the shortest distance that we have conveyed concrete was twelve feet with a quarter yard mixer, and forty-two feet with a half yard mixer. We got a good mixture in both cases.

The water is added with the ingredients as they enter the mixer. It is customary to use about the same amount of water as in ordinary mixing. Personally, I like to have concrete just about wet enough so it will quake all over when you slap it on the top with a spade.

We have no data comparing the pneumatic mixer with other types of mixers. Blocks cut from the Wilson Avenue tunnel were submitted for tests, and they proved satisfactory. The concrete was very dense.

In continuous operation it is not necessary to clean the pipes out unless they have been plugged. A mixer will operate all day without cleaning and at the end of the day's run the operator will blow a batch of water through the pipes and they will shine like a dollar. When a pipe is clogged it is usually caused by low air pressure or by two large rocks bridging across the diameter of the pipe. To break the plug, a light sledge hammer is used to loosen the concrete so that the air can get through at that point. The air will soon tear a hole through the ingredients and clean out the plug. Sometimes it is necessary to hammer three or four minutes to get the plug loosened up sufficiently to get the air through. In a case of that sort it is necessary to add a little water, which acts as a lubricant, to get the plug started. Usually in starting the job a new operator will have half a dozen plugs the first day and then will not have another half dozen in the next month.

For mixing and placing it requires about eight to twelve men, and the quantity which can be placed in a given time depends on the distance the concrete is conveyed. A half yard batch of concrete occupies perhaps three hundred feet of eight-inch pipe line, and it takes about fifteen seconds for it to come out of the end of the pipe. The batch travels just about one hundred feet each five seconds. On a very short line the pipe would be discharging while some of the concrete was still in the mixer.

A six-inch pipe can be used on a half yard mixer if about fifty feet of eight-inch pipe is led from the mixer first. That is, if you attempt to use a six-inch pipe right up to the mixer, it is likely to cause trouble from plugging at the bottom of the mixer. If you lay part of the line about fifty feet out from the mixer, of eight-inch

pipe, so the load can be strung along a little before the mass gets moving, then you can reduce to a six-inch pipe, but the reduction should be made in about three or four feet of length and not in an abrupt reduction.

At the River Rouge plant of the Ford Motor Company there are four half-yard machines working. They use about fifty or sixty feet of eight-inch pipe and then reduce to six inches.

Jets of air at the forward end of the discharge elbow at the bottom of the mixer and at an angle with the axis have been tried, but it does not make any different concrete. The same results are obtained either way, and the more pipes introduced around the lower part of the mixer, the more opportunities there are to stop them up with cement.

In the Twin Peaks tunnel in San Francisco the concrete was full of reinforcement. The same is true of the La Salle Street tunnel in Chicago.

Concrete can be conveyed vertically, although I think it is cheaper to elevate it with an elevator. I don't know how high you can blow concrete if you have the air pressure behind it.

Mr. Libberton: In using this machine at Gary we had considerable trouble in anchoring the pipes. In that work a six-inch pipe broke a quarter-inch cable where it came around a turn. What provision has to be made to prevent the tearing up of the forms where the concrete hits the turn?

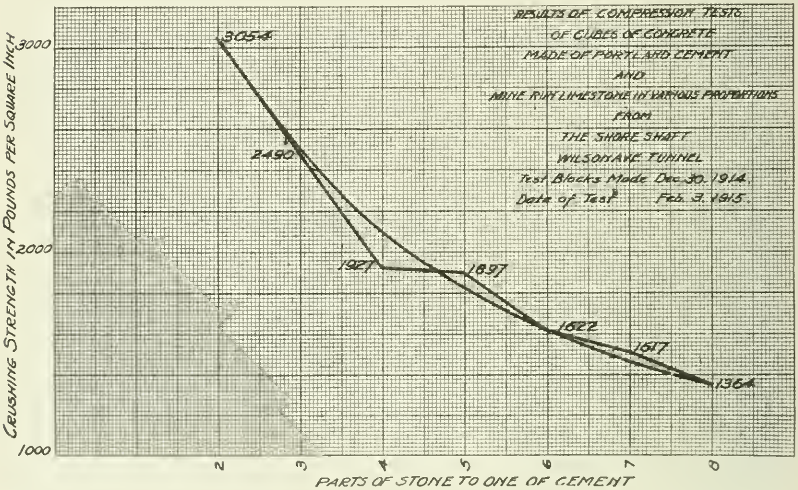
Mr. Kirkland: This system is not adapted to light form work. The speed of the concrete coming from the pipe is about one hundred feet a second, and a half-yard batch coming at that rate could not be placed in narrow forms. With about a ton of concrete coming about one hundred feet a second, whenever it hits a turn in the pipe, the elbow must be anchored very securely. Some of the illustrations show the discharge entering the forms, with a brace at the elbow, and where the elbow was located on top of the form, that was wedged in between the roof and the forms. If there is any chance for the pipe to play at all, it will kick around and perhaps break the flanges. If securely tied, it is all right.

Mr. Wm. Artingstall: The development of the pneumatic mixer is interesting. About fifteen years ago this device was used in connection with an ordinary mixer as a transporting agent. The concrete was dumped into the hopper and transported by air pressure. The contractor, however, put something over on the engineers. He ran a batch of two through the hopper without putting it through the mixer, and discovered that he had a pretty good mix. From that time on it was dropped until about 1907 or 1908, when the Drake Machine Company, here in Chicago, took it up and started to improve it. We tried it out in the La Salle Street tunnel. I think that was the first time it was used after 1903. We made some tests on the concrete, and, as I recollect it now, the ordinary concrete running in a six to twelve-inch cube, withstood a pressure of about 1,900 pounds. We used pressures of about 2,300 to 2,700 pounds

on some forty or fifty different tests. We used this system on account of the convenience more than anything else, but we found we had the best concrete, and we used it practically everywhere we could after that. I think you will find that if the mixers of the present time compare with the ones used at that time, the work will compare favorably with the ordinary mixed concrete work.

DISCUSSION BY LETTER

Mr. Henry W. Clausen, M. W. S. E.: At the beginning of the work on the Wilson Avenue tunnel it was noticed that the rock as blasted from the heading of the tunnel seemed to be well graded in size from the finest up to the largest sizes. A desire to determine what results might be obtained with a mixture of this mine run stone with various proportions of cement led to the making of eighteen twelve-inch cubes, two each of mixtures of varying proportions. These cubes were aged 30 days and then broken in a testing ma-



Curve Showing Strength of Concrete Made of Varying Proportions of Cement and Stone

chine at Armour Institute. The results of these tests are indicated by the curve in the accompanying figure (No. 22). These results were so satisfactory that a recommendation was made to make a layout of automatic machinery to the end that this material would be used for concreting in combination with the compressed air method. A screening and conveying machine was designed, the details of which were described in a paper given before this Society on April 17, 1916.

After the lining was in place, blocks were cut out from the actual tunnel lining at various locations in the cross section, both in

the side wall and fairly well near the springing line. These blocks were from 9 to 12 inches square and from 12 to 20 inches high. The crushing strength per square inch of these blocks ranges all the way from approximately 1,200 pounds to over 3,000 pounds per square inch, the average being between 1,500 and 2,200 pounds. This demonstrated the strength of the lining to be far in excess of any load that would be placed on it, and that it was entirely satisfactory for the purpose.

STRESSES IN SHIPS

By Sydney V. James, M. E.*

Presented April 8, 1918.

The details of the design and construction of ships have been so long regarded as more or less fixed that interest in the considerations which led to the evolution of such items has necessarily fallen off. In particular, steel ships have been fairly well standardized in their construction by the classification societies, such as Lloyd's Register, British Corporation and Bureau Veritas, and of late little has been asked of the naval architect in proportioning the sizes and distribution of structural material other than noting the requirements in regard to such features as specified in the rules of such societies.

With the advent of the reinforced concrete ship, however, interest in the stresses to which a ship is subjected becomes of great importance and in order to intelligently distribute the materials entering into the construction of such ships we must have a definite conception of the nature and amount of the stresses to which a ship is subjected under service conditions. Accordingly, it is the purpose of this paper to review the subject so as to lay before you the fundamental considerations involved.

The first part will be devoted to a general statement and discussion of the kinds of stresses, and the second part to a detailed discussion of the methods of determining the principal longitudinal stresses and a brief statement of some of the results of the application of such methods to the study of ships of well-known type. Although these methods are entirely applicable to the design of reinforced concrete ships, it will not be attempted to cover this matter in the present paper. Brief mention will also be made of the question of shearing stresses and of the situation relative to transverse stress calculations.

PART I.

The stresses to which a ship's hull is subjected may be conveniently discussed under three broad divisions: Longitudinal, transverse and local stress. Although these divisions are not entirely separate and distinct, they may, nevertheless, be taken as the three most important phases of the subject.

LONGITUDINAL STRESSES.

A ship may be considered as a long boxlike structure supported by and propelled through water. Its underwater portion is pointed towards the fore and aft extremities and is wide and full amidships. Certain interior spaces are devoted to machinery, cargo, fuel, stores, water ballast, etc. As the shape of the underwater portion is determined more by considerations of its resistance to propulsion

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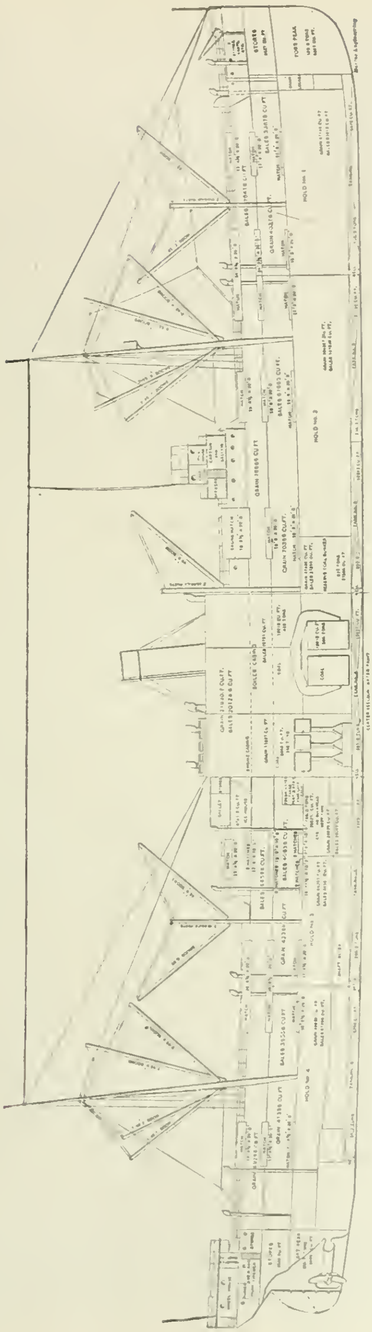

Fig. 1

through the water than by the fore and aft or longitudinal distribution of the weight of the structure and its contents, there arises a condition whereby fore and aft distribution of the buoyant pressure of the water is not the same as that of the weight. Consequently, there is a tendency for the hull to be deformed by the forces set up due to this inequality. In this connection consider Fig. 1, showing the arrangement of a large freighter. It will be noted that the propelling machinery and boilers are concentrated amidships, the cargo spaces are arranged forward and abaft the machinery and boilers and that the extreme ends of the vessel are utilized as tanks called peak or trim tanks used for carrying water for ballast. In addition to these there are such localized weights as masts, derricks, chains, propellers, etc. When such a weight distribution is considered in relation to the shape of the underwater portion of the hull, it will be clear at once that although heavy weights are located amidships where the vessel is widest, many heavy weights are placed near the ends where the buoyant or supporting effect of the water is very small, owing to the small displacement of the pointed ends.

It makes considerable difference in the relative distribution of the vertical forces whether a ship is in still or wave water. To illustrate this point, Fig. 2 has been prepared to show diagrammatically the *tendency* of waves to seriously alter the distribution of the buoyant effect of the water. The upper of the three diagrams shows a ship in still water, W L denoting the water line. In such a condition the hull is immersed to a practically uniform depth.

In the middle figure the ship is shown resting on a wave as long as the ship, a crest being under each extremity. In this condition the buoyant effect of the water is increased at the ends and decreased at the middle. In this condition a ship would tend to sag in the middle like a beam supported at the ends and centrally loaded. The mid-ship section at A B would probably be the location of the greatest stresses, which in this case would be compression in the upper members, such as top sides and upper deck and tension in the lower members such as the lower sides and bottom. Such stresses are commonly spoken of as *sagging* stresses.

The ship shown by the lower diagram has the crest of a wave under its middle portion, causing a redistribution of the buoyant support of the water by changing the depth of immersion of the hull at different points. The ends of the ship are relatively unsupported while the middle is submerged to an abnormally great depth resulting in increased support from the water. Consequently the ends will tend to droop downwards; the upper works at the midship section A B will be put in tension and the bottom in compression. Such stresses are spoken of as *hogging* stresses.

The severity of sagging or hogging stresses in any particular case will depend largely on the distribution of the weights. For instance, in the case of a ship having its engines and boilers situated amidships, the sagging stresses will be the greatest when it has its coal bunkers and amidship water ballast tanks filled and a light

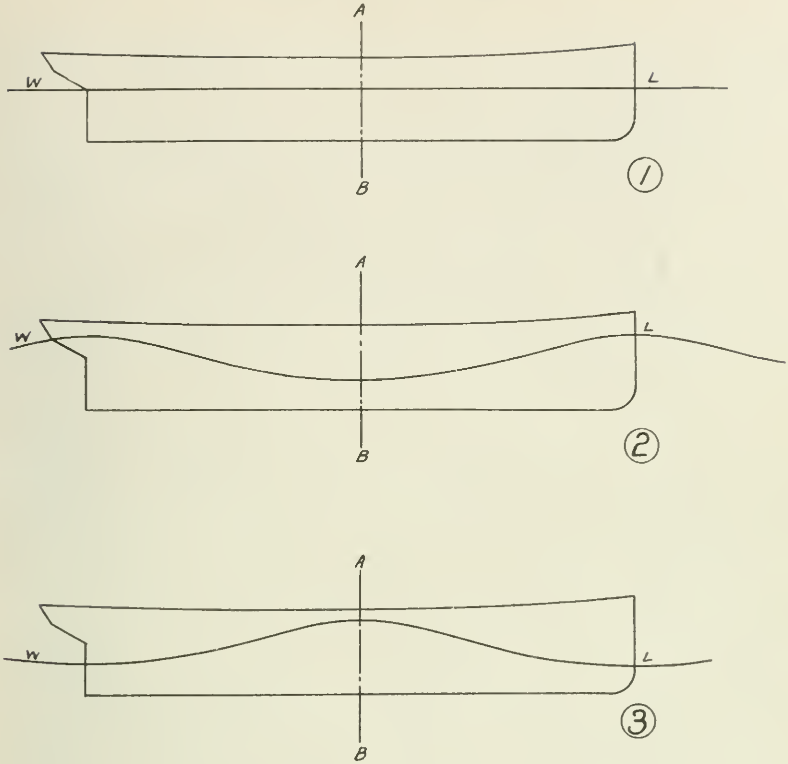

Fig. 2

cargo, the bulk of which is concentrated near the middle of the vessel. If under such loading the end or peak tanks were empty and the ship should encounter, head on, heavy seas in which the length of the waves was approximately the same as that of the ship, the relatively light ends would be well supported when wave crests were under them at the extremities of the vessel. The heavy weights concentrated amidships would augment the sagging effects and the resulting stresses would be high.

On the other hand, imagine the same vessel with cargo holds filled, thus distributing the load well towards the ends of the ship. Towards the end of a long voyage, the coal bunkers may be practically empty and the peak ballast tanks filled. When the crest of a wave equal in length to the ship comes under the midship portion of the vessel, the heavy ends being now relatively unsupported will tend to impose severe hogging stresses in the midship section.

Both sagging and hogging stresses will be somewhat augmented in case the ship is rolling severely while proceeding diagonally across a series of waves and is supported at the extremities or amidships while in an inclined position. Furthermore, the inertia effects of

the mass of the ship may not only alter the amounts, but also the location of maximum stresses when the vessel is heaving and pitching in a seaway. The portable effects of such conditions will be mentioned in Part II.

The fore and aft unequal distribution of vertical loads which gives rise to the sagging and hogging stresses also causes shearing stresses principally in the sides of the vessel. This is readily understood by comparing the ship to a beam supported either at the ends or in the middle and subjected to the vertical forces of the loads and reactions. This will be taken up in further detail in Part II.

Longitudinal stresses are resisted by fore and aft members of the structure such as deck and shell plating, stringers, keel and longitudinal bulkheads.

TRANSVERSE STRESSES.

It is now proposed to consider some of the conditions under which a ship will *tend* to be deformed in a transverse direction. Fig. 3 shows diagrammatically the tendency of each of several well-defined conditions. At No. 1 is shown in outline a transverse midship section of a ship, WL denoting the water line. Obviously, the hydrostatic head of the water exerting pressure on the sides and bottom tends to deform the framework as shown by No. 2. The sides tend to bend inward and the bottom upward. The transverse framing must withstand this tendency. In case a ship is rolling or is struck heavily sidewise by a wave, the tendency is somewhat as depicted by No. 3. The angles formed by the deck and the sides at A and B tend to change and the framing at the points C and D where the sides join the bilge also tends to become deformed. A heavy deck load or the weight of a heavy sea shipped on deck will tend to change the transverse form of the ship by bending the deck downwards as indicated at No. 4. Similarly a load due to cargo or con-

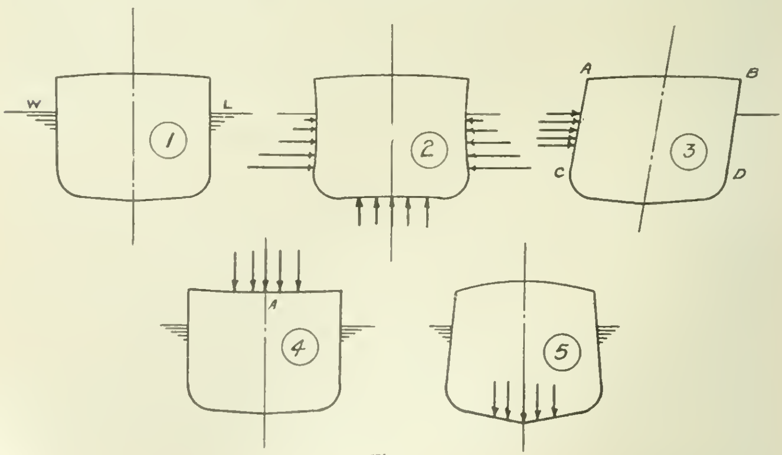

Fig. 3

centrated fixed weights such as machinery will tend to change the transverse form as shown by No. 5.

Effects depicted by Fig. 3 are resisted by such structural features as the side plating, frames, deck beams, stanchions (or columns placed between deck beams and bottom), double bottom transverse bulkheads and other details of construction commonly employed in steel ships.

LOCAL STRESSES.

Besides the stresses caused by tendency to change of form transversely, there are many local stresses brought about by the conditions of service such as panting stresses, stresses due to the means of propulsion, rudder post and plating stresses, stresses due to loading or unloading while aground and launching stresses. Panting stresses are caused by the alternate increase and decrease of wave pressures on the forward end of a vessel while being driven through the water. Such action has a tendency to make the sides work in and out in a manner resembling panting, hence the term. High speed vessels are subjected to more severe panting stresses than slow vessels because of the greater pressure due to the speed. Full or blunt-ended ships present a greater surface to the action of such pressures and hence are likely to experience greater panting stresses than fine-ended ships. The structure is usually specially strengthened to withstand these pressures and so as to minimize deformation and working of the plating.

The propelling machinery imposes stresses on account of the vibration imparted to the entire ship. As every ship has a natural period of vibration, it sometimes happens that the vibrations of the engines at certain rates of speed synchronize with the period of the ship and severe stresses may be set up by the resulting excessive vibration of the entire vessel. Additional stiffening and local strengthening of the hull are often necessary to overcome the possibilities of such vibration, loosening rivets, opening seams and in other ways producing leakage as well as injury to the structure.

Rudder post stresses are caused by the enormous pressure of the water on the rudder when the vessel is turning. The water pressure is particularly severe in the case of large, heavy, high-speed vessels. The rudder requires careful design not only concerning the post proper, but also the body, especially if it be of the type having a central frame with plating on each side. This sort of rudder may have panting stresses set up in it to such an extent as to loosen rivets, unless proper filling and fastening are employed.

Trading ships are sometimes required to enter tidal rivers and harbors where, when the tide is low, they lie aground. The weight of cargo being loaded or unloaded will, especially if the bottom is uneven, tend to bend and distort the ship's bottom. Cases have been known where bending of the ship has occurred due to the harbor bottom supporting the hull at widely spaced locations.

Closely related to the foregoing is the matter of a ship acci-

dentally grounding at high tide and remaining fast with one end supported by the ground and the other by water. It sometimes happens that a ship will ground amidships at high tide. In such cases very severe bending stresses may be set up and ordinarily no attempt is made to allow for such conditions at the time a ship is built.

When the weight of a vessel is being transferred from the launching ways to the water during the ordinary operation of launching, bending stresses are imposed, but they are usually less in magnitude than those imposed by waves in the manner previously discussed. Such moments arise due to the after-end of the ship, in launching by the stern, being water-borne, while the forward end is still resting on the ways. Sagging stresses are, therefore, caused and unless the ship stops on the ways, no serious consequences follow. If the vessel should stick part way down the ways before the

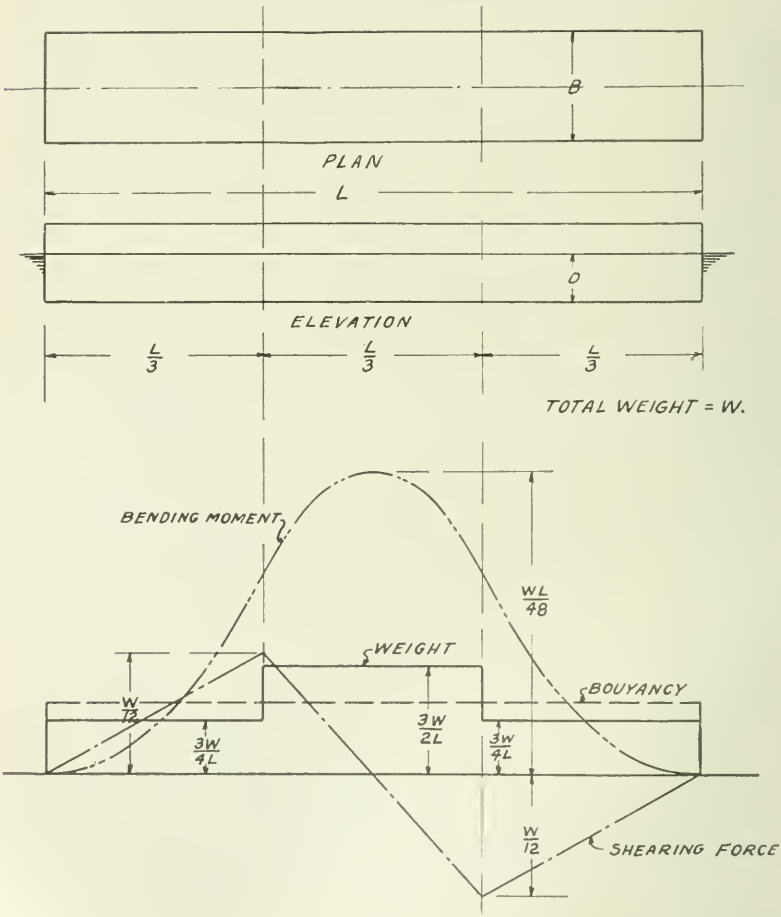

Fig. 4

stern is water-borne, large hogging stresses may be set up due to the unsupported end overhanging the ways. The bottom may experience local crushing of a serious nature. The cradle supporting a ship has a special supporting member near the bow called the fore poppets. It is at this place that the weight of the forward end of the hull is concentrated at the time the rear end becomes supported by the water and accordingly there is a severe pressure on the hull plating which must be carried by the entire transverse structure.

PART II.

LONGITUDINAL STRESSES.

Having briefly discussed the principal kinds of stresses, it is now proposed to indicate how the longitudinal stresses are determined. As an introduction, consider the case of a simple vessel shown in plan and elevation at the top of Fig. 4. This, as you see, is rectangular in plan, elevation and section. For the sake of discussion it has been assumed that the middle third weighs twice as much as either of the end thirds of the length. This assumption is made to roughly approximate the actual ship having engines and boilers amidships. On the base line at the bottom of the figure we have the broken line representing the distribution of the weight. The ordinate of each end portion is $\frac{3W}{4L}$ since each end third of the length equals one-quarter of the total weight and the product of the length of the end portion, $\frac{L}{3}$, and the ordinate $\frac{3W}{4L}$ equals $\frac{W}{4}$. Similarly the ordinate of the middle portion of the weight "curve" is $\frac{3W}{2L}$, since this portion is twice as heavy as each end third.

The line representing the longitudinal distribution of the buoyancy is, of course, at a constant distance from the base line, since the draft D is constant throughout the length of the vessel. The ordinate is $\frac{W}{L}$. The difference of the ordinates of the weight and buoyancy "curves" at any point represents the vertical unbalanced force or load acting at that point. Thus throughout the end thirds the buoyancy of the water exceeds the weight and there is a resultant upward force, while throughout the middle third the weight exceeds the buoyancy.

Now by a well-known relationship of the mechanics of beams, the summation of the loads up to any given section from the left end represents the shearing force. This will, as usual, be considered "+" if the part to the left of the section tends to slide upwards

and "—" if downwards. Accordingly, summing up the loads beginning at the left end we can draw the shear curve as shown, reaching a maximum of $+\frac{W}{12}$ at the end of that first third of the length. Continuing the process the remainder of the curve is drawn as indicated. The shear becomes zero at the middle of the vessel and $-\frac{W}{12}$ at the end of the middle third of the length.

By another well-known relationship it will be sufficient to integrate the curve of shearing forces up to any given section to obtain the bending moment at that section. Accordingly, the curve of bending moment was obtained by taking the total area under the

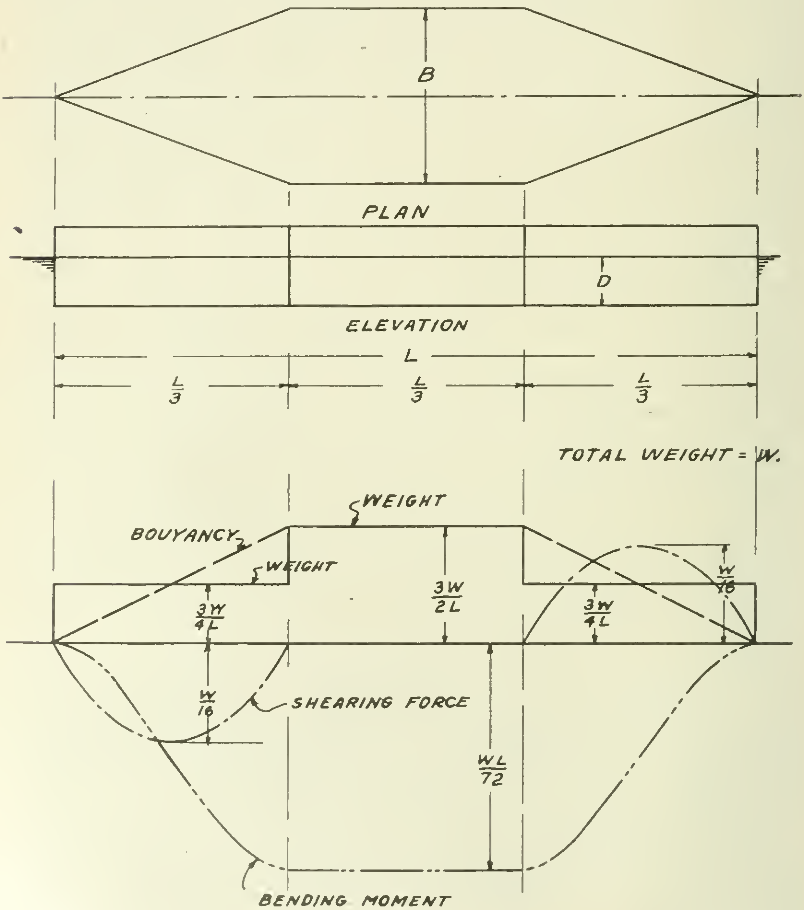

Fig. 5

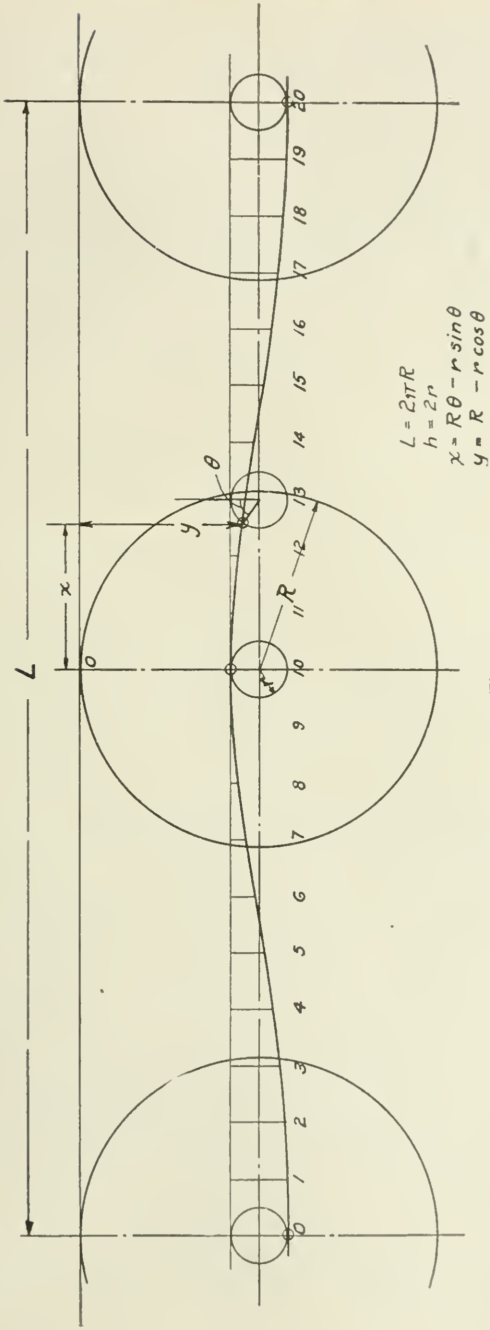

Fig. 6

shearing force curve up to any section. The curve is plotted above the base line since the moment tends to bend the end to the left of the given section in an upward direction. The maximum value of $\frac{WL}{48}$ is reached at the midship section and the ordinate at each end in zero as shown. This vessel is subjected to a sagging moment.

Consider now the case of the hypothetical vessel shown by Fig. 5. In this case the draft is constant at D as before, but the end thirds are pointed. The middle third weighs twice as much as either end third as in the preceding example. The weight "curve" is as before. The buoyancy "curve" rises from zero at the ends to the ordinate $\frac{3W}{2L}$, which is constant throughout the middle third of the length. It will be noted that the loads at the ends exceed the buoyancy, hence starting at the left end the shearing force will be minus. Summing up the difference between buoyancy and weight as in the previous case, the shearing force curve is drawn, attaining a value of $-\frac{W}{16}$ at the middle of the left end third, zero throughout the middle third, and $+\frac{W}{16}$ at the middle of the right end third. The integration of the shearing force diagram gives the bending moment curve as shown, with a value for this case of $-\frac{WL}{72}$. The minus sign denotes a hogging moment.

Before applying the principles involved in these diagrams to the case of an actual ship, it is well to take up at this point the contour of the wave surface upon which the ship is to be placed as outlined earlier in this paper. It has been found that waves in deep water may be closely approximated by a geometrical form of a wave profile known as a trochoid. Referring to Fig. 6 the large circle with radius R is supposed to roll on the upper horizontal line. A point on the smaller circle with radius r traces a wavelike line as shown. Such a curve is a trochoid and is the typical wave surface used by naval architects in longitudinal strength calculations. The diameter of the tracing circle is taken to represent the height of the wave and the length is, of course, the circumference of the rolling circle. $L = 2\pi R$ with the origin of coordinates at O, and values of x and y as indicated, the equations representing these coordinates are:

$$x = R\,\theta - r \sin\theta$$
$$x = R - r \cos\theta$$

The angle θ is the angle through which the large circle has rolled up to the point in question.

As a typical deep sea wave has a height about 1/20 of its length, this proportion is chosen for the wave used in calculation for ships 200 feet or over in length, and the diagram shows a trochoid of this character. In other words, L is 20 times the diameter of the small (tracing) circle. For convenience in laying off such a wave quickly, the following table may be used in which the value of the ordinate is expressed in terms of the height, $h = 2r$, and is given for each of the stations from 0 to 20 as marked. The ordinate lengths are taken from a horizontal line tangent to the top of the wave. The short lines drawn in on the diagram are the lengths referred to in this table.

TABLE FOR LAYING OFF TROCHOIDAL WAVE HAVING HEIGHT 1/20 OF LENGTH.

Station No.....	0	1	2	3	4	5	6	7	8	9	10
Ordinate in Terms of h....	1	.982	.932	.843	.720	.576	.421	.275	.128	.036	0
Station No....	20	19	18	17	16	15	14	13	12	11	10

For use in longitudinal strength calculations such a wave is drawn having a length L equal to that of the ship. Then for the sagging stress calculations the wave contour is laid on the ship drawing with the hollow amidships and adjusted vertically by trial and error (using the ordinary methods of calculating the buoyancy up to the wave line) until the weight of the water displaced is equal to weight of the complete ship under the chosen conditions of loading. In this work it is assumed that the water pressure at any point is strictly proportional to the depth below the surface. The error involved by this assumption will be discussed later.

Similarly for the hogging stress calculations the wave contour is placed with the crest amidships and adjusted until the proper displacement is indicated by the calculations based on the assured conditions of loading.

The vessel is assumed to be held on to the waves and to remain upright in the athwartship direction. Effects introduced by considering the vessel inclined will be considered later. It is further assumed that the waves pass so slowly that dynamic effects such as pitching and heaving may be neglected and the vessel regarded as instantaneously at rest. Consideration of the effects due to pitching and heaving will be taken up after the simpler case has been examined. No account is taken ordinarily of changes in distribution of buoyancy due to elastic deflection of the vessel.

In determining the maximum stresses due to sagging it is customary, in case of a merchant ship, to assume the ship to be loaded with as much weight amidships as the most extreme conditions will allow. This usually means that any amidships coal bunkers are filled, any water ballast necessary is assumed to be in amidships tanks and any cargo is to be taken as occupying the hold spaces nearest to the midship portion of the vessel. The end or peak ballast

tanks are assumed to be empty. To illustrate, the application of such conditions to the case of a typical small merchant ship, consider Fig. 7. The various curves are denoted by wording on the diagram and were obtained in a manner similar to that employed in the simpler cases previously mentioned. The ship in question was 200 feet long between perpendiculars, had a moulded breadth of 31 ft. 10½ in., and a moulded depth (to upper deck) of 22 feet. The maximum bending moment, determined by scaling the original diagram, was found to be 9,700 ft. tons. (The units usually employed in ship calculations involving bending moment; the "long" ton, 2,240 lbs., is meant.)

In determining the maximum stresses due to a hogging moment, the weight distribution is taken as the opposite extreme to that described for sagging. The cargo holds are supposed to be filled and the peak tanks carrying water ballast. Any bottom tanks near the ends are supposed to be filled. The hogging diagram for the ship previously mentioned is shown by Fig. 8. Here the maximum bending moment measured 14,400-ft. tons.

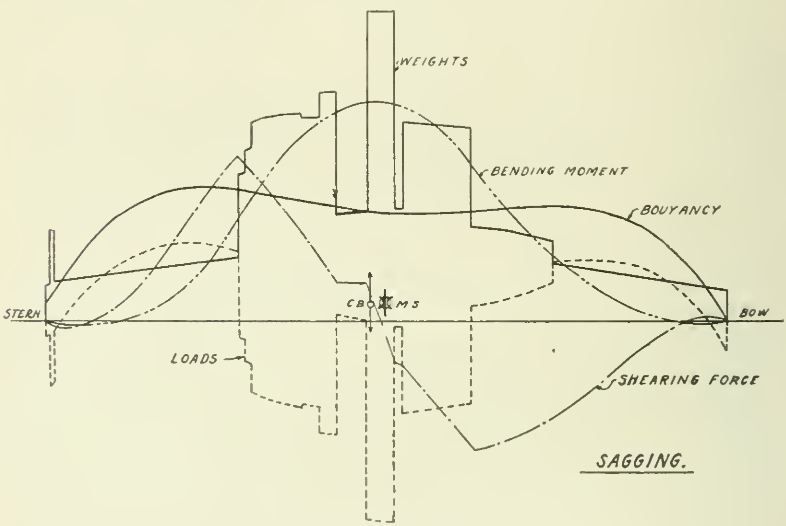

Fig. 7

In order to avaluate the stresses to which the extreme top and bottom portions of the structure are subjected, it is necessary to calculate the moment of inertia of the weakest section near the point of maximum bending moment. Methods ordinarily used by engineers for calculating the moment of inertia of the section of any compound girder are applicable here. These will not be discussed further than to say that if certain parts of the structure may not be depended upon to take compression and other parts

to take tension, it will be necessary to calculate two values for moment of inertia, one for sagging and the other for hogging stresses. These will have correspondingly different neutral axes.

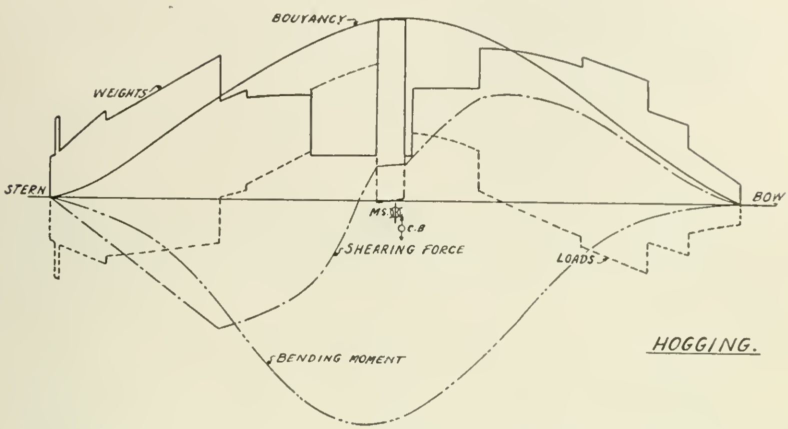

Fig. 8

In the case of the small merchant ship the diagrams for which have just been considered, the moment of inertia for sagging was found to be 7,770,040 in.[4], and the distance of the extremities of the strength section from the neutral axis were, top, 169 inches; bottom, 104 inches. Consequently the stresses may be determined by substitution in the usual formula: $f = \frac{Me}{I}$, where f = intensity of stress per unit of area,

M = bending moment.
I = moment of inertia.
e = distance from neutral axis to extreme outer fiber.

Applying this to the problem in hand, the compression in the upper deck will be

$$f_c = \frac{9700 \times 12 \times 169}{7,770,040} = 2.54 \text{ tons per sq. in.}$$

or about 5,700 lbs. per sq. in. The tension in the bottom plating at the keel will be

$$f_t = \frac{9700 \times 12 \times 104}{7,700,040} = 1.56 \text{ tons per sq. in.}$$

or about 3500 lbs. per sq. in.

The maximum hogging stress bending moment was found to be 14,400 ft. tons and the moment of inertia, 7,123,000 in.[4] The values

of "e" were 187 in. to top and 86 in. to bottom. Hence the tension in the deck is

$$f_t = \frac{14,400 \times 12 \times 187}{7,123,000} = 4.53 \text{ tons per sq. in.}$$

or about 10,200 lbs. per sq. in.

Similarly the compression in the bottom is

$$f_c = \frac{14,400 \times 12 \times 86}{7,123,000} = 2.1 \text{ tons per sq. in.}$$

or about 4,700 lbs. per sq. in.

It has been found that the intensity of stress at the point of maximum bending moment may be conveniently determined by the aid of what is known as the intensity factor. This is expressed as follows:

$$F = \frac{WL}{M_{max.}}$$

where F is the intensity factor, W the total displacement weight of the vessel in tons (2,240 lbs. each), L the length between perpendiculars in feet and $M_{max.}$ the maximum bending moment.

The following table of values, taken from Murray's "Strength of Ships," shows the average values of the intensity factor for different kinds of vessels.

VALUES OF INTENSITY FACTOR.

		Hogging.	Sagging.
War Vessels	Large battleships....	30	50
	Large cruisers.......	25	30
	Small cruisers.......	24	25
	Destroyers	20 to 23	17 to 20
Merchant Vessels	Fast Atlantic liners...	20 to 25	30 to 35
	Large cargo and passenger	22 to 28	18 to 20
	Small cargo and passenger	30	25
	Large cargo.........	25 to 30	15 to 25
	Small cargo.........	25	20

The maximum tensile and compressive stresses to be allowed in practice depend on such conditions as probable usage and estimated life of the vessel, kind of cargo to be carried, materials employed and size of vessel. In speaking of the stresses to be allowed the length of the vessel comes into the problem because, based on the usual or standard assumptions, the wave is taken with a height 1/20 of the length and for extremely long ships such an arbitrary condition would impose higher stresses than those to which the same ship would probably be subjected in actual waves. Such long ships

would seldom encounter waves equal in length to the ship and, furthermore, such long waves may have heights less than 1/20 of their lengths.

The approximate stresses to be allowed, based on the standard methods of calculation, have been summarized by Murray in "Strength of Ships," as follows:

ALLOWABLE STRESSES.

		Tons per sq. in.	Llbs. per sq. in.
Battleship	Tension	7	16,000
	Compression	6	13,500
Destroyer	Tension	9	20,000
	Compression	7	16,000
Large Atlantic Liner.	Tension	8-10	18,000 to 22,500
	Compression	6- 8	13,500 to 18,000
Cargo and passenger boat (400 to 500 ft.)	Tension	8	18,000
	Compression	6	13,500
Cargo boat (about 300 ft.)	Tension	4.75	10,500
	Compression	3.75	9,000

In the case of a very large passenger or cargo and passenger vessel, stresses as high as 13 tons (29,000 lbs.) per sq. in. have been allowed.

In discussing the assumptions to be made in determining the bending moment it was said that among other things the vessel was taken to remain upright. If the vessel is inclined at the time the extreme sagging or hogging stresses are imposed, the maximum values as obtained by the standard method may be increased anywhere from 10% to 20%, depending on the angle of inclination. It will not be attempted to derive the formula which applies in this case, but for a point located at a distance x from the longitudinal plane of symmetry of the ship and at a distance y above the neutral axis in the erect position, the intensity of stress may be found by substitution in the following formula:

$$f = M_{max.} \left(\frac{y}{I_x} \cos\theta + .\frac{x}{I_y} \text{ cx} \sin\theta \right)$$

in which f is the stress per unit of area, $M_{max.}$ the maximum bending moment, x and y are the coordinates of the point in question (usually the extreme upper corner of the deck at the high side of the midship section), θ is the angle of inclination of the ship, I_x is the moment of inertia of the cross section about the neutral axis when the ship is erect and I_y the moment of inertia about the vertical axis when the ship is erect. In ordinary calculations I_x is determined and it is only necessary to calculate I_y by a similar method.

An application of this formula by Prof. Biles (Trans. Engineers & Shipbuilders of Scotland) has shown a maximum value of "f" about 20% in excess of the "f" for the ship erect when inclined at an angle of 30° (degrees).

Another item deferred for consideration was the assumption that the pressure or buoyancy of the water is proportioned to the depth below the surface of the wave. A correction based on a study of the dynamics of trochoidal waves is called for because it can be shown that the water pressure is less than normal at the crest of a wave and greater than normal at the trough of a wave. Accordingly, the increased buoyancy due to crests will be actually less than that shown by the standard calculations and the decreased buoyancy of a wave hollow will be less than the standard. Both these effects will diminish somewhat the bending moments. Hence the standard calculations give a basis on the safe side. The reduction in the moments has been found to vary from 5% in the case of small vessels to 12% for large vessels.

There are two other effects spoken of previously which alter the maximum bending moment. These are heaving and pitching.

Heaving is vertical oscillation of a ship and pitching is the oscillation about the transverse gravity axis. In heaving a ship sinks and rises vertically and in pitching it dips and rises alternately at the bow and stern. Heaving has been investigated and it has been found that, due to the inertia of the entire mass of the ship the maximum bending moment in waves of standard proportions may be increased about 10% for relatively long ships.

Pitching has a tendency to increase the bending moment between the point of maximum determined by standard conditions and the ends of the ship. It may in some cases bring the bending moment at points about 1/3 of the length from the ends of the vessel to a value equal to the maximum near the midship section. This effect and the consideration of shearing stresses, to be discussed in the next paragraph, generally warrant increased strength at the regions of the ship at a distance from 1/4 to 1/3 of the length from each end.

To take up the question of shearing stresses it will be noted by reference back to Figs. 7 and 8 that the greatest vertical shearing forces occurred at about 1/4 of the length from either end of the vessel. The cross-section at this region should, therefore, be investigated to make sure that the intensity of stress per unit of area due to shearing will be within safe limits. It can be shown that the intensity of shearing stress varies considerably throughout the section of any girder or beam and that it reaches a maximum at the neutral axis. The formula for the intensity at the neutral axis is to be found derived in any standard work on mechanics and reads as follows:

$$s = \frac{V}{It} Ay$$

where s is the shearing stress per unit of area, V is the vertical shearing force at the section in question, I is the moment of inertia of the section, t is the width of the section at the neutral axis, A is the area of the section on one side of the neutral axis, and y is the distance from the neutral axis to the center of gravity of the area A. In other words, Ay represents the statical moment of the area on one side of the neutral axis and this is already available from the detailed computations required to obtain the moment of inertia.

It may be of interest to see what result is obtained by applying this to the case of the small cargo steamer for which the logging diagram was calculated and shown as Fig. 8. The maximum shearing force in this case was 274 tons, the whole sectional area at the section of maximum shearing force was 788 sq. in. The statical moment, Ay, of the formula, figured out to be 36,264 in.^{3} The moment of inertia was 7,599,152 in.^{4} and the combined thickness of shell plating was $2 \times .44$ or .88 in.

Hence the maximum shearing stress was found to be

$$s = \frac{274 \times 36{,}264}{.88 \times 7{,}599{,}152} = 1.48 \text{ tons per sq. in.}$$

or approximately 3,330 lbs. per sq. in. This, it will be observed, is considerably larger than the average shearing stress figured for the entire section as follows: $\dfrac{274}{788} = .35$ tons per sq. in. or about 785 lbs. per sq. in. Further considerations are usually involved, such as investigation of the intensity of shearing stresses in the rivets of the shell plating seams, and it may be necessary in some instances to increase the riveting at the neighborhood of maximum shear from double to treble riveting.

We have discussed the question of longitudinal stresses and the shearing stresses due to longitudinal loading. Such stresses may be somewhat readily approximated as we have seen, but no simple method readily applicable has as yet been discovered whereby transverse stresses may be determined. On this account steel ships have been designed on an empirical basis established by the classification societies and fully covered by their rules. Compliance with such requirements or their equivalents is necessary in order to obtain insurance on the finished vessel. Such a procedure is ordinarily quite satisfactory when designing a steel ship, but with the substitution of other materials, such as reinforced concrete, it becomes of interest to know how to distribute the concrete and reinforcing steel so as to provide adequate transverse strength. The most practicable method now available, it seems to the writer, is to design the transverse members so they will be equivalent in strength to the steel members which would be required for a ship of the same size and character. Such calculations could be based on some arbitrarily

assumed conditions of loading and should be sufficiently exact for this purpose.

Attempts have been made in the past to investigate the transverse strength of a ship by an application of the principle of least work and reference may be made to an historic paper on this subject by J. Bruhn, published in the "Transactions of the Institution of Naval Architects," 1901. The method there indicated has been extended and applied by A. J. Murray in his "Strength of Ships." The conditions assumed in such calculations involved the depth of water, i. e., the water pressure on the hull, and the stiffness of the framing members. The numerical work required is long and tedious and owing to the unknown effects of rolling and pounding of the ship in a heavy sea, not to mention the possible shifting of cargo incident thereto, it does not appear to be profitable to carry out such computations. In certain cases they may be of value as far as determining relative strength of different structures is concerned.

It is hoped that the foregoing remarks have placed before you the main features to be considered when the stresses in ships are to be determined. It is also hoped that those of you who are interested in the future possibilities of ships constructed of material other than those well-tried in ship service will have been brought to realize the peculiar problems involved. Much has been said and written recently about the use of reinforced concrete as a substitute for steel construction and we are all vitally interested in such possibilities especially at this time when the problem of building many ships quickly has been complicated by shortage of labor and materials. The substitution of concrete for steel should be thought out carefully and conservatively, bearing in mind the peculiar stresses to which a ship must be subjected.

CLOSURE

Mr. James: Since a number of interesting points have been brought out by the discussion they will be briefly considered.

The Intensity Factor referred to on page 370 is of great value in approximating the required strength of a ship's hull in the original preliminary design. The table on page 370 gives values to be chosen for the case in hand and enables the designer to make a fairly close estimate of the longitudinal bending moment for either hogging or sagging. Thus the bending moment in foot-tons will be approximately equal to the displacement in tons, W, multiplied by the length in feet, L, divided by the Intensity Factor.

Another feature brought out was the probable variation in the stresses in a ship's hull when moving in different directions relative to the crests of long waves. A ship moving at right angles to the line of the wave crests would be subjected to severe longitudinal bending moments which would alternate in direction and intensity as the ship occupied different positions relative to the crests or hollows of the waves. The transverse stresses would be compara-

tively low. On the other hand, a ship moving parallel to the wave crests would be subjected to heavy rolling (transversely) and accordingly the transverse stresses would be high with probably minimum longitudinal bending moments. There would probably be some direction of motion intermediate between these two extremes on which the ship would be subjected to a combination of the two stresses producing a minimum unit stress in the material of the hull.

This question brought up two other closely related items: (1) Whether or not there are portions of the hull which do not suffer reversal of stress, and (2) Torsional Stresses. The first question had reference to the placing of reinforcement in a concrete hull where there were regions where the stress did not reverse and where it might be necessary to run only one series of reinforcing bars. The question is difficult to answer definitely and it would be safe to say that there are probably reversals of stress in all important portions of a ship's hull. The extreme stern of the vessel in the case of an overhang might not be subjected to reversal, but this would involve a very small percentage of the ship's structure.

While undoubtedly a ship is subjected to torsional stresses, no attempt is made to calculate or estimate them. Ships are usually designed on an empirical basis in which past practice and experience form the most reliable guides. Ships capable of withstanding the transverse and longitudinal stresses already outlined are also capable of safely resisting any torsion to which they may be subjected in service.

The use of models in the study of ship's stresses has been confined principally to tests of the comparative strength of details of construction such as deck beam knees or brackets.

The classification societies of different countries carry out work very similar to that outlined in connection with Lloyd's of England. Most of the large nations have such organizations, but the fact that Lloyd's Register includes over half the world's tonnage speaks for the importance of this one society and for the regard which ship owners have for its recognition.

It was asked whether or not the thickness of the shell plating as determined by Lloyd's tables depends on the length of the ship or the frame spacing or other items of construction and whether or not such thickness is sufficient to allow an ample margin of strength. The tables are based on all the principal dimensions of the ship as well as on the proportion of length to depth. The tables are arranged in order of two governing numbers known as the Transverse Number and the Longitudinal Number. These are carefully defined by Lloyd's and the tables are based on these numbers so that for any particular ship it is only necessary to calculate these governing numerals and enter the tables at the corresponding lines, to pick out the scantlings required.

Adverse criticism of this ship design was brought forward during the discussions and it was suggested that independent thought based on correct analysis of the stresses might result in a better

ship structure. This is true, but the difficulty and delay in getting the proposed construction passes on by the classification society as the equivalent of the standard ship more than offsets the benefits of the slight difference in the design.

The sudden shifting of cargo or the rushing of people to one side of a boat, such as happened in the Eastland disaster, is a matter involving more especially the transverse stability of the vessel and is properly allowed for in the calculations covering this phase of the design.

IN MEMORIAM

JESSE LOWE, MEM. WESTERN SOCIETY OF ENGINEERS

DIED APRIL 17, 1918

Our Society, in the inevitable order of events, is called upon at irregular intervals to chronicle the passing of one and another of its honored members. The men who have done things are leaving the field to the men who are doing things. Jesse Lowe was preeminently a man who had done things and was doing them until the end came April 17th of this year (1918). We are told that he was born January 7, 1861, at Omaha, Neb. From the source from which we derive this information we learn that he attended private and public schools in the city of his birth. That later he was a student in the Maryland Agricultural College, a military academy. Next he attended Williston Seminary at East Hampton, Mass., and then went to Rensselaer Polytechnic Institute at Troy, N. Y., and was graduated from there in 1885. Thus we learn that his educational advantages were exceptionally good and we know that they were imparted to a mind capable of making splendid use of this equipment of knowledge. His record of service is long and honorable and what he built remains to testify that he was indeed a master builder.

After his graduation Mr. Lowe was, for a short time, assistant to the city engineer of Omaha, and assistant engineer in locating the Omaha Belt Line Railway, and in the preliminary and location surveys of the Missouri Pacific Railroad west of Omaha. In 1886 he was employed at Lincoln, Neb., as resident engineer of the Missouri Pacific Railroad.

He went next to Birmingham, Ala., as assistant manager of the Birmingham Bridge and Bolt Works. In 1887 he formed a partnership with the late Andrew Rosewater, M. Am. Soc. C. E., and George B. Christie, M. Am. Soc. C. E., and was extensively engaged in civil engineering in the Middle West. The following year this firm was dissolved, and that of Christie & Lowe, civil engineers and contractors, was organized and continued until 1913. Mr. Lowe was always an active member of the firm, which was engaged in important engineering works in many parts of the United States, among which were the following:

The Cable Street Railways at Denver, Colo., in 1889; the cable lines of the Cleveland Street Railways Company at Cleveland, Ohio, and the street railways of the Judson Pneumatic Railway Company at Washington, D. C., in 1890; the Montague Street Cable Railway at Brooklyn, N. Y., in 1891; the completion of the cable system at Denver in 1892-93; the piers for the Bellefontaine Bluffs Bridge over the Missouri River and the Harlem Creek Culvert, in St. Louis, Mo., for the Kansas & Northwestern Railroad, in 1892; the Fullerton avenue loop in Chicago, in 1892, the first underground trolley line in America; and the V Street Railway, in Washington, D. C., which was the first in that city. The success of this last piece of work

revolutionized street railway construction and was the pioneer engineering work in doing away with overhead electric wires and placing them underground.

The firm of Christie & Lowe as contractors for work on the Sanitary and Ship Canal of Chicago justified a previously earned reputation for efficiency and reliability. On December 23, 1893, they entered into contract with the District for excavating sections I and K of the main channel, aggregating 8,690 feet in length, and requiring the excavation of 2,308,415 cubic yards of earth. The final voucher for this work was reported November, 1896, or two years and ten months after the contract was entered into. Original and eminently successful methods used by these contractors enabled them to accomplish such great results in that short period. (See in the proceedings of the Society for the year 1897, page 670, a description and illustrations of the Christie & Lowe method.)

On January 18, 1896, Christie & Lowe entered into contract with the Sanitary District of Chicago for constructing the controlling works at Lockport, except the masonry for the Bear Trap Dam. These controlling works consisted of seven stony gates and a bear trap dam. Of this aggregation of mechanism the bear trap dam was the difficult feature. While it was of the type of structure known as bear trap, it was different from any design of that type theretofore constructed and was a more daring structure in dimensions. The design was evolved by Assistant Chief Engineer T. T. Johnston, ably assisted by Ernest L. Cooley and J. H. Spengler. So original were the features of this structure that suggestions for betterment were invited from the contractors, and this is indicated by a clause in the contract which reads: "The second party shall submit plans in detail of all of the work covered by this contract and where the same differ in any way from the plans provided by the party of the first part, to be approved by the Chief Engineer before work is commenced thereon." The contractors secured the services of Mr. Alfred Noble to collaborate on this work, which stands today, strong because of its material, but workable because of the genius of the men whose brain power was fabricated into the steel structure.

In 1897 the firm did railroad and bridge work for the Illinois Central and Louisville & Nashville Railways; levee construction on the Illinois River; and in 1899, bridge foundations at South Chicago for the Baltimore & Ohio Railroad.

From 1898 to 1913 the firm was engaged in river and harbor improvement for the United States Government, and completed, in order, the jetties at Sabine Pass, Tex.; at Calcasieu Pass, La., and at the mouth of the St. Mary's River, Cumberland Sound, Fernandina, Fla.; locks and dams on the Warrior River, Alabama; jetties and improvement of Southwest Pass of the Mississippi River, Louisiana; closing of Pass a l'Outre and Cubits Gap, Mississippi River, Louisiana; and sea walls at Fort Morgan and Fort Gaines, Mobile Bay, Alabama.

Mr. Lowe was always an ardent advocate and a valiant cham-

pion of the Lakes-to-the-Gulf Deep Waterway project, both as to its beneficial bearing on the vast acreage of adjoining valley lands and for the improvement of the transportation facilities from the lake territory to the Gulf ports.

During his later years he was actively engaged in drainage and reclamation work on the Illinois River and in improving and managing extensive land holdings at Beardstown, Ill.

Mr. Lowe's sudden death on April 17, 1918, at Chicago, Ill., came as a great shock to his many friends. He leaves behind him, from coast to coast, a series of monuments which for ages to come will testify to his great ability and success as a civil engineer and builder.

He was a member of the Chi Phi Fraternity, American Society of Civil Engineers, Illinois Society of Engineers, Louisiana Society of Engineers, and the Structural Engineers' Association of Illinois.

He became a member of the Western Society of Engineers January 2, 1895.

Isham Randolph.

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings

Meeting No. 1005, May 6, 1918.

This was a regular meeting of the Society. There were present fifty-three members and guests. The meeting was called to order by Mr. K. B. Miller, Second Vice-President. The Secretary announced the death, in service, of Lieut. Kenneth M. Copley, who was killed in an aeroplane accident in France on April 29th.

Mr. George Weston, M. W. S. E., Chief Engineer Board of Supervising Engineers, Chicago Traction, presented a paper on the subject "Discussion of a Unified Transportation System for the City of Chicago." This paper covered the history of rapid transit and the important feature of the report of the Traction and Subway Commission for a unified system of rapid transit. The paper was illustrated with numerous slides and was discussed by Messrs. John W. Mabbs and Charles V. Weston.

Meeting No. 1006, May 13, 1918.

This was a meeting of the Bridge and Structural Engineering Section. There were present eighty members and guests of the Society. Mr. G. A. Haggander, Chairman of the Section, presided. A moving picture showing the installation of equipment and the trial trip of the concrete ship "Faith" was shown.

The Secretary announced the action of the Board of Direction in electing ten new members and presented the names of seventeen applicants for membership.

Mr. H. B. Kirkland, M. W. S. E., presented a paper on the "Pneumatic Method of Concreting." This paper was illustrated with slides, showing the actual work in progress and the plant equipment required.

Meeting No. 1007, May 20, 1918.

This was a meeting of the Hydraulic, Sanitary and Municipal Section. There were present forty members and guests of the Society. Mr. Linn White, Vice-Chairman of the Section, presided.

Mr. Charles B. Burdick, President of the Western Society of Engineers, gave a brief description of the work and character of construction employed in the Porto Rico cantonment.

The paper of the evening was presented by Mr. O. C. Simonds, M. W. S. E., on "Thoroughfares." The speaker emphasized the importance of planning thoroughfares and the choice of grade and alignment. The opportunities of beautifying the roadsides were also emphasized. The paper was discussed by Mr. M. C. Tobias, A. W. S. E., who illustrated the method of determining the radius of curbs at street intersections in order to accommodate automobile traffic. Mr. R. F. Schuchardt, M. W. S. E., presented a written discussion with regard to the thoroughfares as a solution of the transportation problems.

Meeting No. 1008, May 27, 1918.

This was a joint meeting of the Electrical Engineering Section, W. S. E., with the Chicago Section, A. I. E. E., and the Chicago Section, I. E. S. There were present sixty-one members and guests. The rules approved by the Board of Direction for the Sections of the Western Society of Engineers having been previously read to the Section were, on motion duly made and seconded, adopted as the rules of the Electrical Engineering Section.

This being the regular meeting of the Chicago Section, A. I. E. E.,

for the election of officers for the ensuing year, the following were declared elected

Chairman....................................C. A. Keller
Director, three years.........................W. R. McGovern
Secretary ....Arthur F. Riggs

The paper of the evening was presented by Mr. F. A. Vaughn, Consulting Engineer, Milwaukee, Wisconsin, on the subject of "Regulation of Street Series Lamps in Practice." This was a very interesting description of the late development in the transmisson of electric energy in the new street lighting system in Milwaukee, Wisconsin.

EDGAR S. NETHERCUT, Secretary.

BOOK REVIEWS

Modern Management Applied to Construction. By Daniel J. Hauer. First Edition. 194 pages, illustrated. Published by McGraw-Hill Book Company, Inc., New York. Price, $2.50.

Every contractor realizes today that the old methods of conducting business is fast disappearing and that new scientific systems are taking their places. Not only is business being specialized, but every man's daily work is being analyzed into first principles. The system extends from the start of the job to the very finish and includes office management, purchasing, bookkeeping as well as hiring and handling men on the job.

Each business may be different and yet each is susceptible to an analysis whereby the conduct of the business may be systematized so that at every point the contractor may have a record of the work, to enable him to reduce his costs in some places, increase the output of men and equipment, and build up an aggressive organization capable of earning good profits. In exceptional times, such as the last two years, it will permit the rapid expansion of the organization necessary to handle some of the large "war orders" or contracts which have so successfully been put through.

In a general way, this book is a summary of the author's wide experience in contracting and in applying the principles of scientific management to various lines of work. This is supplemental by the experiences of others. Notably the organization charts used on several large projects. The book aims to help the contractor, large or small, in arranging his business on a scientific basis. Only a man with a wide experience and a happy faculty for determining the essential and valuable points of organization could gather so much useful material in one volume. Many of the principles detailed are applicable to the smallest business and a study of them will show even the well-established contractor where he can build up his organization.

Among the subjects treated in detail are: Scientific Management, Finances and Efficiency, Fundamentals in Choosing Type and Amount of Plant, Application of Motion and Time Studies, Cost Keeping and Book Keeping, Systematizing Construction and Effect of Modern Management upon Bookmen. Each subject is treated in a wholly practical manner and in language within the comprehension of every contractor, while the illustrations indicate how the author's suggestions may be properly carried out.

C. A. M.

Labor Problems Under War Conditions. Complete report of the Proceedings of the National Conference held under the auspices of the Western Efficiency Society and The Society of Industrial Engineers.

Probably every employer of labor believes that he is working his men to the best advantage, and yet nearly every one of those men do their work in pretty nearly their own way. Some employers have found that the usual way is not always the best, that a change in routing, handling, etc., would effect a saving, increasing the output of the plant and reducing the cost. Some have gone further and shared the increased profits with the employes. How far this can be done is a problem, for the employe is usually antagonistic to any change, believing it only a ruse to get more work out of him or to lower his wages. Mutual confidence is necessary for labor efficiency, and it is probable that the delegate to this convention went back with numerous ideas for improving this relation to better conditions and to effect real savings which would be profitable to workman and company.

Among the speakers were both men and women who have given this subject serious study. Their addresses and the discussions which followed are given very fully and cover a multitude of phases adaptable to varied lines of work.

C. A. M.

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CONCRETE CAISSONS SUNK BY THE OPEN DREDGING METHOD

L. W. Skov, A. W. S. E.*

Presented June 10, 1918.

In the construction of ordinary Railroad bridges, it is quite frequently necessary to put the footings a considerable distance below the ground line or the bed of the stream, in order to obtain a good foundation or to eliminate danger from scour. It is in foundation work of this kind that the concrete caisson sunk by the open method of excavation has its field. By the selection of proper design, concrete caissons sunk by this method can be built to cover a large variation of soil and sinking conditions. The caisson can either be completely built over its final location, before the sinking operations start, or it can be partly built, sinking started and additional sections of concrete added from time to time as the sinking progresses.

If the location of the pier is in the wet part of the channel, the caisson may be built on temporary staging and lowered to position on the bed of the stream by the means of lowering screws. In other cases the caisson may be built on an artificial island.

Some of the reasons for the use of the concrete caisson are:

First. The elimination of wooden or steel sheet pile cofferdams, which must necessarily be made larger than the neat dimensions of the footing, in order to allow room for wales and bracing.

Second. The walls of the concrete caisson are practically impervious to water, whereas even the best wooden or steel cofferdams allow a considerable amount of water to pass through the walls, in this way adding materially to the amount of pumping which must be done.

Third. The finished structure is one solid piece of concrete, no timbers being imbedded in it, as would be the case where a construction requiring interior bracing is used.

Fourth. The amount of timber required for forms for a concrete caisson is very much less than that required for building cofferdams. This, of course, is a very great advantage at the present

*Assistant Engineer Bridge Department, C., B. & Q. Ry., Chicago.

time, as the Government has reserved all of the larger sizes of timber for shipbuilding and other Government construction activities.

Fifth. The amount of equipment required is reduced, inasmuch as it eliminates the use of sheet pile driving equipment, and allows a reduction in pumping equipment.

Sixth. Eliminates the pulling of sheet piling, where the leaving in place of the sheet piling is objectionable.

Seventh. Saves time in construction, as it is not necessary to first drive a cofferdam.

DESIGN AND CONSTRUCTION

The walls of the caissons are designed for a variable unit load equal to that usually used in designing retaining walls holding an earth fill. In cases where a considerable head of water is expected the hydrostatic pressure is added to the above unit pressure. When the caissons are rectangular in shape $\frac{w\ l^2}{8}$ is used for computing the bending stresses, no account being taken of continuity between the several sections of wall formed by the cross struts, no reinforcing being placed on the outside face of the caisson at points opposite the cross walls. While this is not theoretically correct, no signs of failure have been noted from this cause. The bottom of the side-walls and interior struts are tapered down to a width of from 3″ to 1 ft. on the bottom, to form a cutting edge. Where caissons are sunk through clay or sand it is customary to leave the concrete cutting edge unprotected; where gravel, rip rap or other hard materials are encountered the cutting edge is protected by steel angles or hardwood timbers, depending on the material through which the caisson is to be sunk. Steel protected cutting edges are not used except where the material penetrated is very hard and offers a great resistance, as the hardwood cutting edge is found to give better protection to the concrete and on account of its greater width gives a much stronger caisson wall near the bottom.

One half inch sq. bars, spaced about 1 ft. centers are placed vertically in the walls to tie the concrete together and to help distribute local loads over a greater area of wall. Openings are left in the interior walls of sufficient size to allow the free passage of men and tools from one chamber to another in caissons where the excavation is to be done by hand. The walls of the caissons are made of 1:2:4 concrete and the core of 1:3:6 concrete. The only reinforcing used in the core are the stub bars for tieing on the neat work. These bars are spaced about 2′ 0″ centers and are only counted on to prevent temperature cracks. In the larger caissons where the excavation is removed by the use of grab buckets or pumps, the interior walls are usually stopped off about 2′ above the cutting edge and no holes left between the various compartments.

In cases where caissons are sunk to eliminate danger of scour, it may be found necessary to drive piling to carry the load. In this

case the piles are driven in the usual way, after the excavation has been completed. Caissons sunk under these conditions are usually full of water and require sealing around the piles with a tremie. After the concrete has sufficiently set, the water is pumped out, the piles cut off, and the balance of the caisson filled with concrete.

When it is desirable not to have the caisson project above the ground line a triple lap wooden cofferdam is built on top of the concrete caisson, the lower wale being bolted to the concrete. When the pier has been constructed it is an easy matter for a diver to remove this wooden crib by just unscrewing the nuts on the bolts holding down the cofferdam.

Figure 1 shows one of the first concrete caissons built by the C., B. & Q. R. R. Here steel angles and plates were used to protect the concrete cutting edge, the cutting edge being made very narrow

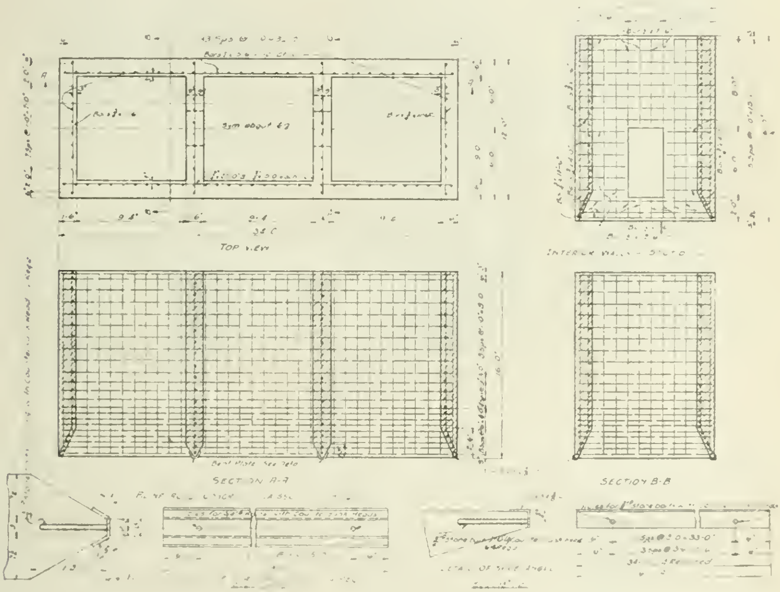

Fig. 1

to insure sinking of the caisson by its own weight. It has, however, been found by experience that it is not necessary to employ as narrow a cutting edge as the one used for this caisson.

This caisson was excavated by hand, the material being removed by a hoisting engine having two nigger-heads placed on the ends of the drum shafts, from which ropes were run through sheaves attached to the old bridge, directly over the caisson locations. These ropes were provided with sling arrangements which hooked onto

the wheelbarrow wheel and handles. The loaded barrow upon reaching the top of the caisson was pulled over to one side of a platform and then wheeled over and dumped on the river bank. The excavating gang consisted of twelve men, and an average of twelve yards was excavated daily. A boulder four feet in diameter, resting on the bedrock and located directly under one of the caisson walls, was encountered. As the boulder rested on bedrock, it was thought

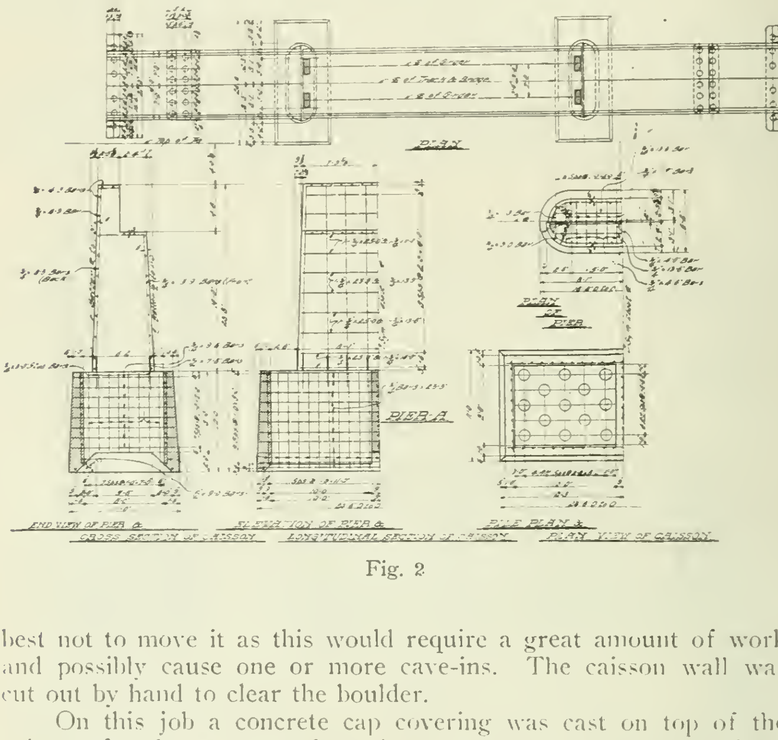

Fig. 2

best not to move it as this would require a great amount of work and possibly cause one or more cave-ins. The caisson wall was cut out by hand to clear the boulder.

On this job a concrete cap covering was cast on top of the caisson, for the purpose of making a more nearly watertight joint between the caisson and the core. Subsequent experience has shown that this is not necessary. This caisson was built in 1911.

The caisson shown in Fig. 2 was built in 1912, one year later than the one shown in Fig. 1. It will be noted that the design of cutting edge has been changed, and that no protection is used for the concrete. The cross struts or walls have been raised up two feet above the cutting edge. This allows a passage for the water from one compartment to the next and in that way reduces the pumping problem to a minimum. The outside of the walls have also been tapered off toward the top, the idea being to reduce skin friction. It having been found, however, that the difference in friction for the straight wall and the battered wall is very small, the battered wall

design has been discarded on account of the greater cost of forming. No opening was made in the strut wall as the caisson is not a very high one.

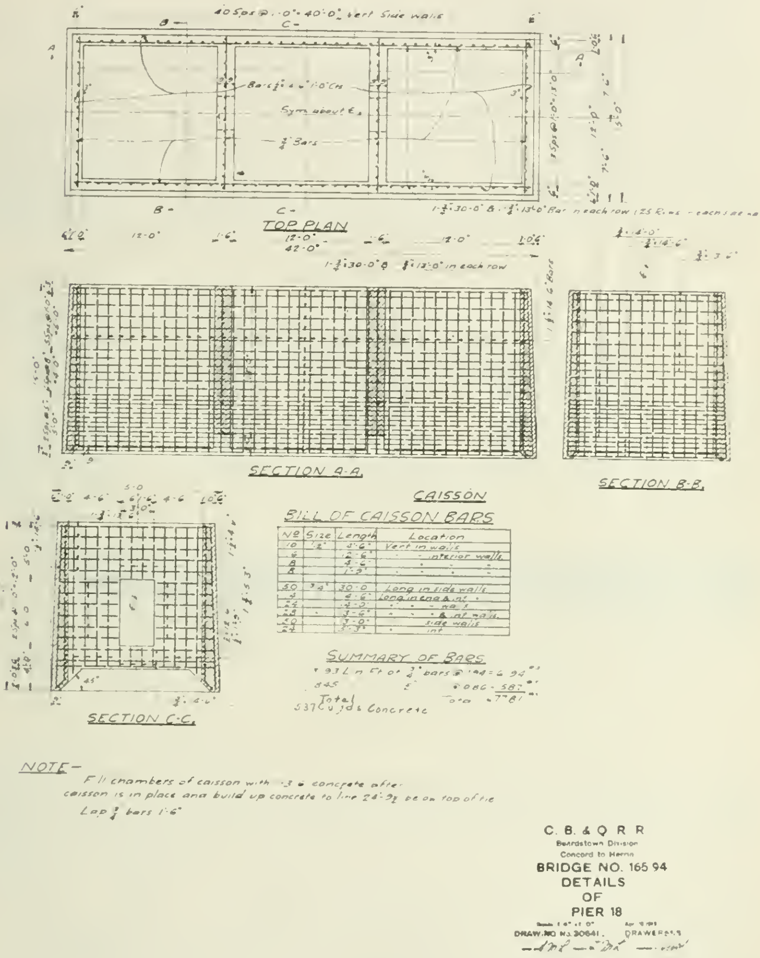

Fig. 3

This caisson was hand excavated, the material being removed by shoveling in stages. As the caisson was sunk for the purpose of getting below the scour line, and as there was no hard ground here near the surface, softwood piles were driven to carry the load. This caisson was sunk through clay, and only a small amount of water was encountered.

Figure 3 shows another caisson built in 1912. It is considerably larger than the one shown in Fig. 2, otherwise the design is quite similar. Here, on account of the greater height of caisson, an opening for communication between the various compartments was built.

This caisson was sunk through stiff clay, and for a while considerable trouble was being experienced in making the caisson settle. Even after the excavation had been removed below the cutting the box would remain suspended. It so happened that the old bridge at this point was a pile trestle, the new caissons being built between the old pile bents. The foreman one day conceived the idea that it would be possible to put up struts resting on the top of the caisson and long enough to reach the bottom of the stringers of the trestle bridge which would deflect under load, and then let a

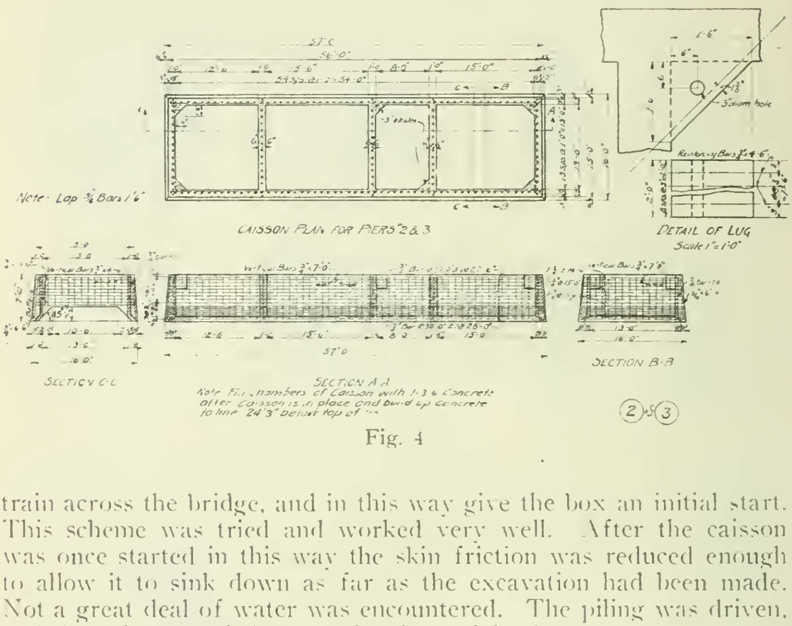

Fig. 4

train across the bridge, and in this way give the box an initial start. This scheme was tried and worked very well. After the caisson was once started in this way the skin friction was reduced enough to allow it to sink down as far as the excavation had been made. Not a great deal of water was encountered. The piling was driven, and the caisson sealed as previously explained.

Figure 4 shows the caissons used in the reconstruction of bridge No. 311.83 over the Black River near Lytle, Wis. Here the caissons were built on platforms resting on piling. The piles under the old truss were driven by a locomotive driver; the piles outside of the trusses were driven by a floating driver. The piling were driven in a rectangle, clearing the outside dimensions of the caissons about one foot, the spacing varying from 5 to 7 feet along the perimeter of the caisson. The piles were then cut to grade and capped with one 12" x 12" fir timber halved at the joints and fastened to each pile with a ⅞" x 2' 0" drift bolt. Wedges

3 inches thick were placed on top of the cap at intervals of 3 feet and a 4" x 12" bolster placed on them. On these 4" x 10" bolster stringers were placed 1'6" centers, with one 12"x12" timber under each end wall. This construction was then floored over with 3" x 10" plank and forms erected, reinforcing steel placed and concrete poured. The concrete was delivered in ½ yard dump cars run on a track built on ties extended beyond the trusses.

After a lapse of time sufficient to let the concrete set, the caissons were raised clear of the platform by tightening up the six 2¼" lowering screws. The lowering screws were supported on pairs of old girders resting on pile bents driven outside the platform piles. The wedges were then removed thus leaving clearance to remove the plank flooring and stringers with ease.

Lowering was then started by simultaneously slacking up the nuts on the six suspension rods. This required 2 men for each screw using wrenches with gas pipe handles. The weight of the concrete alone in each of these caissons is 105 tons.

As these caissons could not be built more than 7 feet high and clear the old bridge, it was necessary to extend them by the use of timber cribbing on top of the concrete, as lowering progressed. The caissons had to be lowered about 16 feet before landing. This lowering was accomplished at the rate of about one foot per hour.

The underlying material is sand and old logs; the sand was removed by submerged centrifugal pumps. During the sinking of one of the caissons 219 water logged logs were encountered and were removed by breaking them up with a spud bar just outside of the caisson walls and then pulling them up through the inside of the caisson.

Next the foundation piling was driven under water, a locomotive driver being used for the piles coming under the old truss spans and a floating driver for the remainder; a follower was used in both cases. Upon completion of pile driving the caissons were sealed to a depth of about 3 feet, the concrete being deposited through a tremie.

The caissons were then pumped out, the piles cut off and the pier completed.

Figure 5 shows a caisson sunk in the Missouri River at Kansas City. This caisson was built on made ground, retained by a dyke of cement sacks filled with sand. The sinking conditions here were very unusual, as the land side of the caisson had to penetrate a rock ledge while the river side was resting in sand and an old garbage dump.

The rock was blasted, using dynamite, and removed by loading on skips and raising with a derrick. Considerable trouble was encountered from the water breaking in on the river side of the

caisson. Several logs were removed from under the cutting edge by pulling them into the caisson. One large log encountered about 10 feet below the ground line had to be cut off outside of the caisson before it could be pulled in. The water trouble was finally

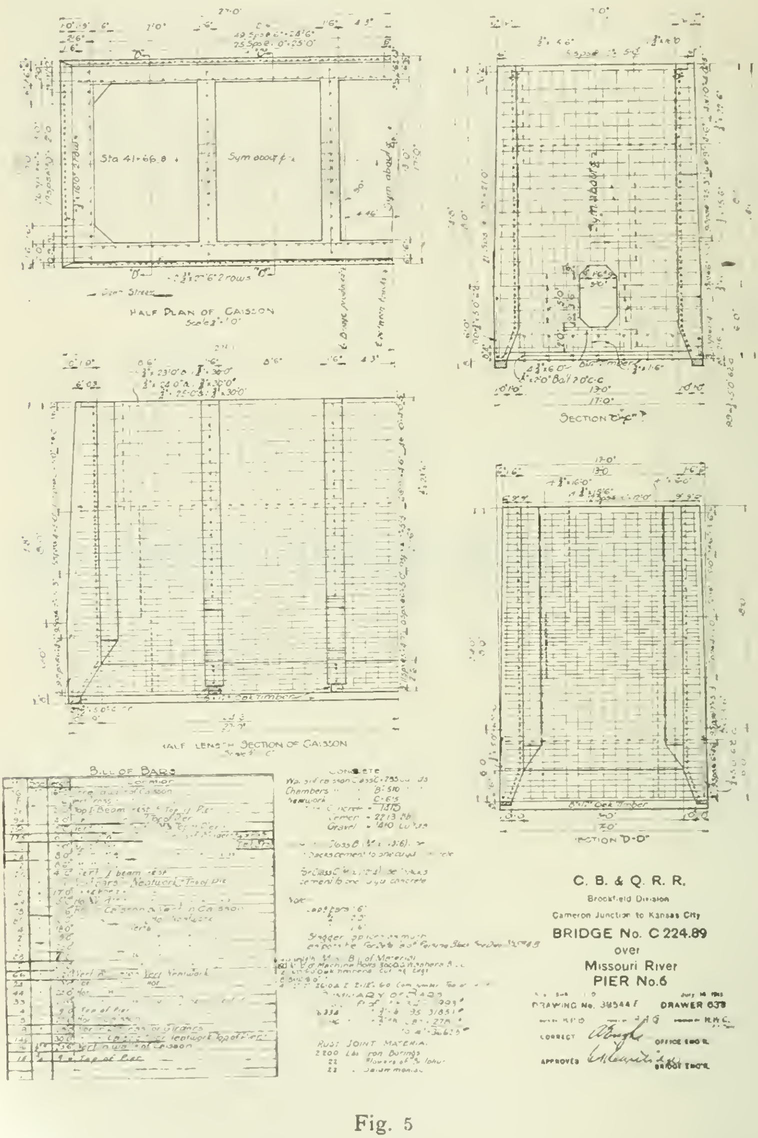

Fig. 5

overcome by the liberal use of cinders placed along the river side of the caisson and the caisson landed on a rock bottom.

Figure 6 shows the caisson used from pier No. 8 of the Metropolis Bridge and is the largest concrete caisson ever built by the

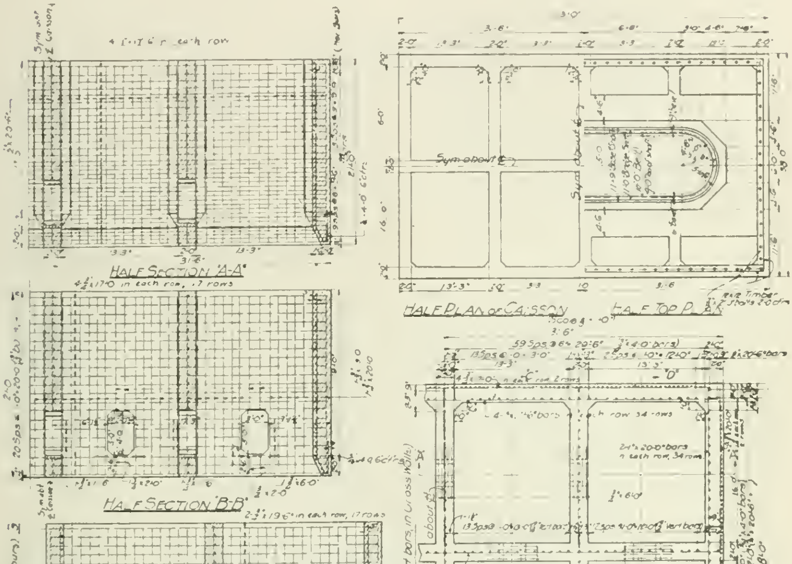

Fig. 6

Burlington. This caisson was sunk through a sandy clay to a depth of 50 feet below the ground line where a sand foundation was obtained. Originally it was planned to sink this caisson about 35

feet, but when this depth was reached the soil was still unsatisfactory to carry the large loads coming on this pier, so it was decided to continue sinking until satisfactory foundation could be had at a depth of 50 feet as previously stated. This caisson was started just before one of the greatest high water periods ever known on the Ohio River set in, and had to be temporarily abandoned as the water rose way over the top of it. The water remained up for a considerable length of time. After the water had fallen sufficiently to make the ground dry around the pier, work was again started. The timber cofferdam shown in the figure had been wrecked by the high water and was substituted by building an additional 16 feet of concrete caisson on top of the original one. On top of this a timber crib consisting of 12″ x 12″ timbers laid one on top of the other was built. Struts of 12″ x 12″ timbers divided this crib into the same number of compartments as the concrete caisson below.

The excavation was removed by two clamshells operated from stiff leg derricks resting on pile supports driven at opposite corners of the caisson. Upon completion of excavation, 129 soft wood piles were driven with long leads extending down into the caisson. The driver rested on top of the wooden crib and was easily moved from pile to pile. After all the piles had been driven the caisson was sealed through 40 feet of water, a tremie being used.

After the concrete had sufficiently set the caisson was pumped out and the remainder of the concrete poured in the dry.

It will be noted in figure 6 that the caisson was not completely filled with concrete, but open pockets were left along the two sides of the pier, resulting in a considerable saving of concrete. Upon completion of the pier to the top of the concrete caisson the timber crib was removed, letting the dirt fall into the open side pockets. All the timber was salvaged, which consequently left a pier without any timber struts running through it as would have been the case had open cofferdam construction been employed.

Figure 7 shows a type of caisson used for double track construction, this type makes possible a large saving of concrete.

Figure 8 shows a type of caisson similar to the one shown in Fig. 7 except that it is sunk to a greater depth. This caisson was sunk through sand and clay, excavated by hand and built in 1918.

Here the headroom was very limited, making it necessary to construct the caisson in sections as the sinking progressed.

Figure 9 shows a type of caisson used where it is necessary to sink to a great depth. In cases of this kind a considerably larger caisson would be required if it were to be constructed of wood, thus adding a large amount of additional excavation, also area subject to skin friction and at the same time reducing the average weight per cubic foot of volume. This will be more clearly seen when we remember that as timber weighs only about two-thirds as much as water, it will require a considerable amount of concrete or other ballast to be placed in a timber caisson before any weight is

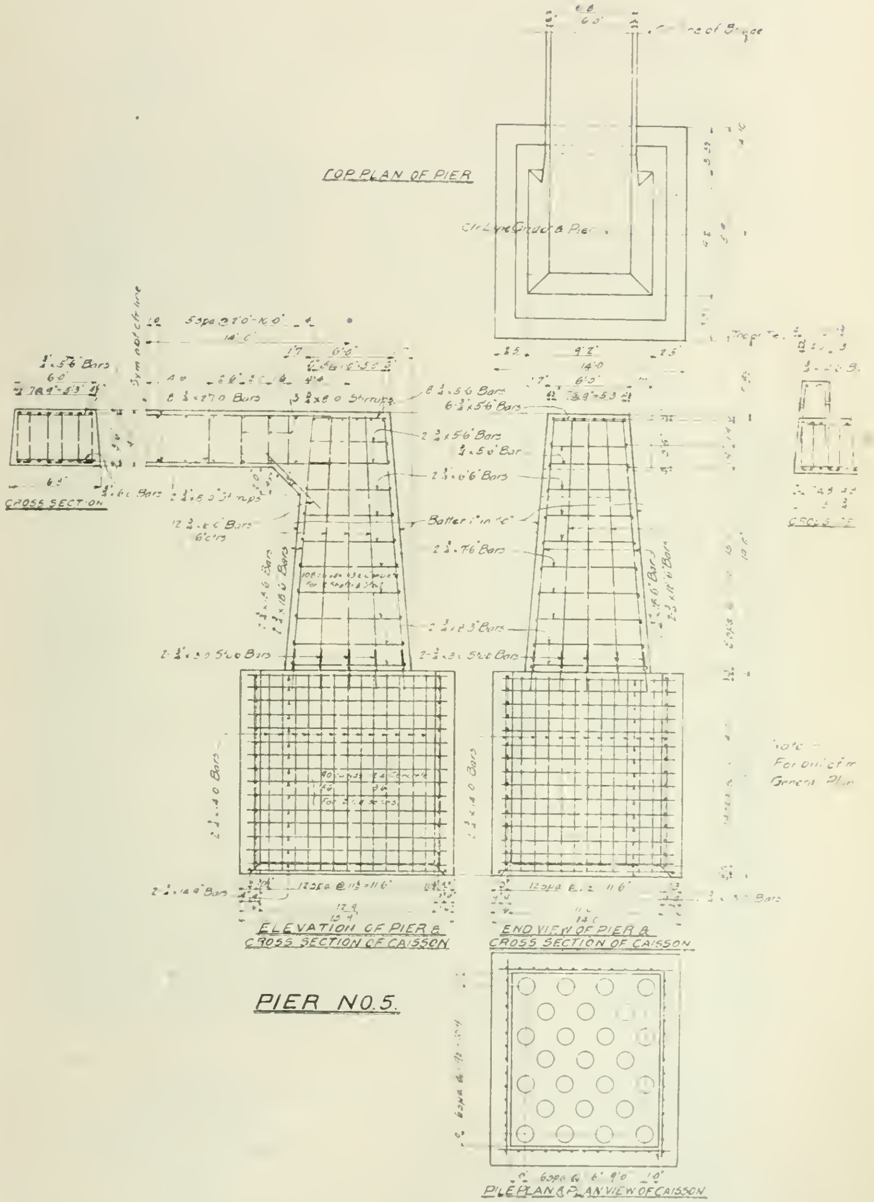
TOP PLAN OF PIER
CROSS SECTION
ELEVATION OF PIER & CROSS SECTION OF CAISSON
END VIEW OF PIER & CROSS SECTION OF CAISSON
PIER NO.5.
PILE PLAN & PLAN VIEW OF CAISSON

Fig. 7

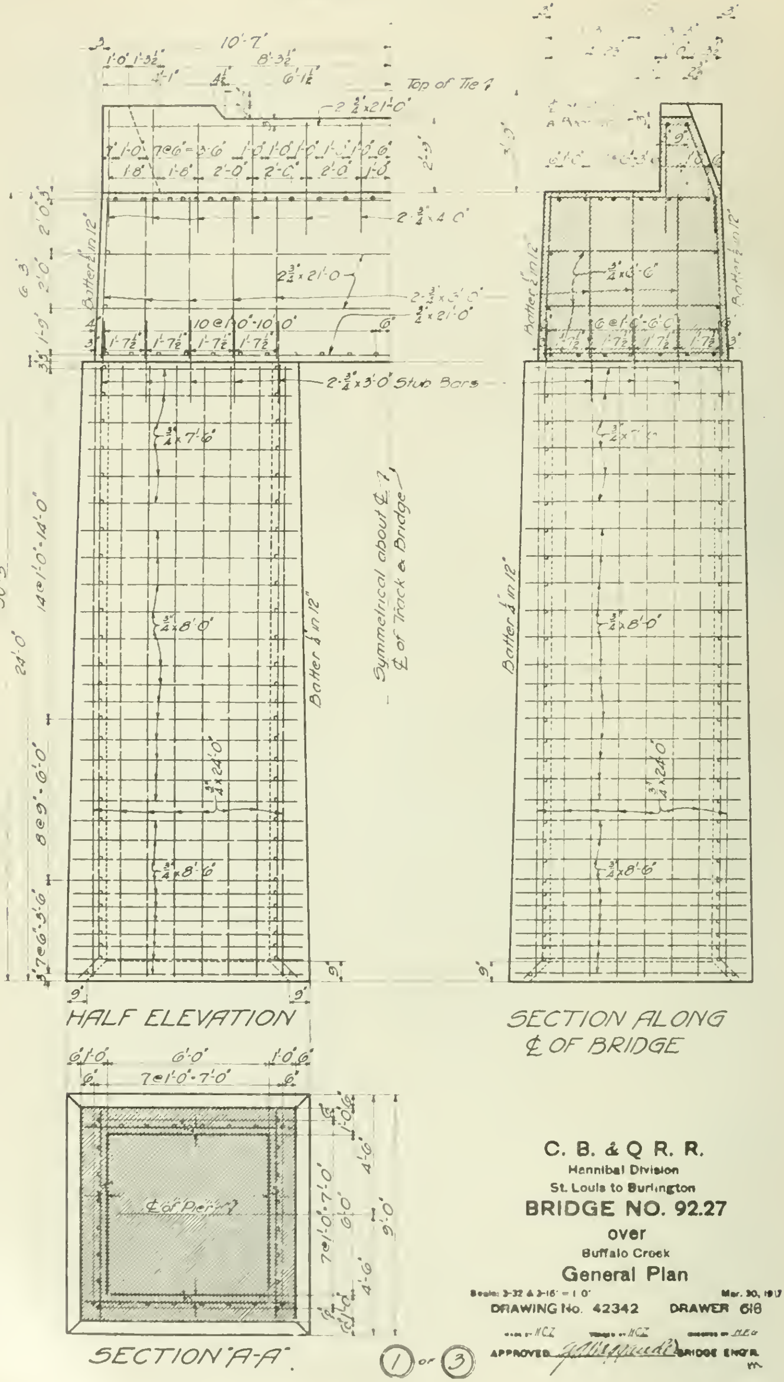
HALF ELEVATION
SECTION ALONG ℄ OF BRIDGE
SECTION "A-A".
Top of Tie
2-¾"x3'-0" Stub Bars
Symmetrical about ℄ of Track & Bridge
Batter ½" in 12"
C. B. & Q R. R.
Hannibal Division
St. Louis to Burlington
BRIDGE NO. 92.27
over
Buffalo Creek
General Plan
DRAWING No. 42342
DRAWER 618
APPROVED
BRIDGE ENG'R.
① of ③

Fig. 8

available for the overcoming of skin friction. The overcoming of the skin friction of rest usually requires ballast of some kind even with concrete caissons when sunk to a considerable depth. The extra weight of the concrete caisson over that of the timber caisson is a very large advantage.

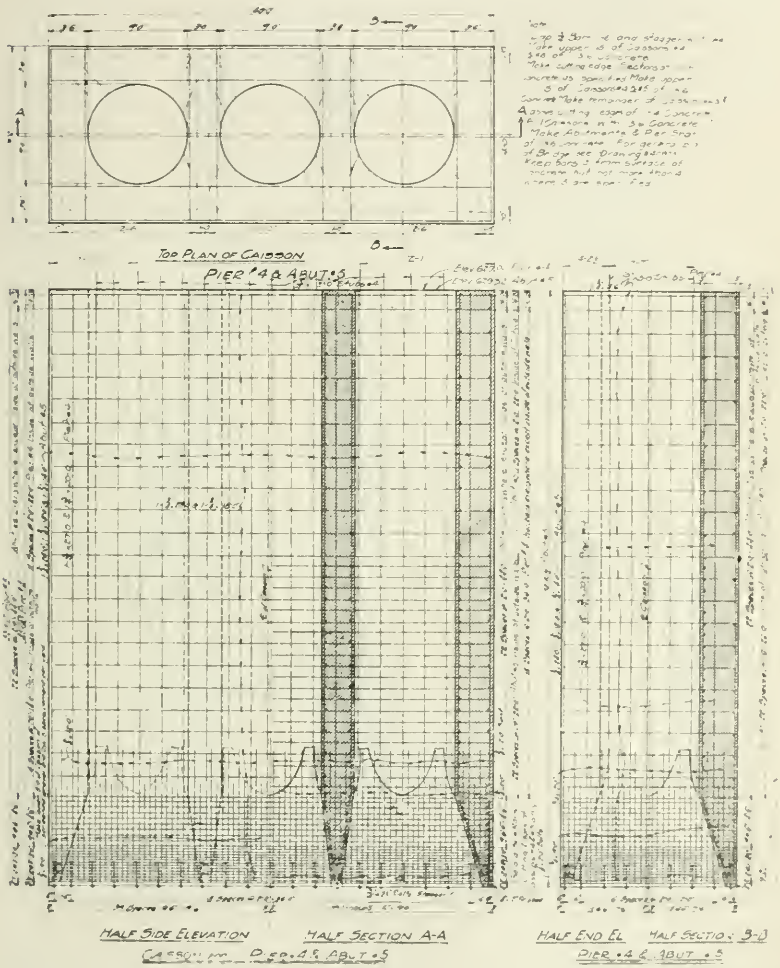

Fig. 9

This caisson was built on an island of sand, pumped in from the riverbed by the same dredge boat that was used for placing the railway embankment along the river. Numerous soundings were taken at the location of the outside faces of the caissons in order

to determine the exact shape of the rock bottom at the site of each pier. The cutting edges were then built to conform to these contours. This feature would greatly have complicated the framing of timber caissons.

The sand was removed partly by a clamshell operated from a stiff-leg derrick set up on piling driven before the temporary island was made and by the use of sand ejectors. The details for this are shown in Fig. 10. This ejector works on the same principle as the self-lifting boiler injector, except that a stream of water is passed through the nozzle instead of steam. The water

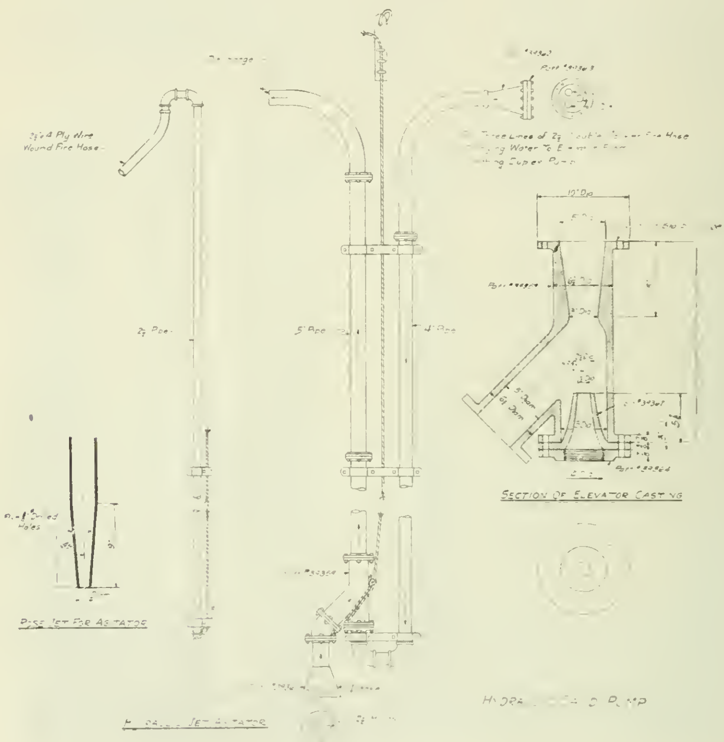

Fig. 10

was delivered through a 4-inch pipe line to the 3-2½-inch flexibles from a Deane duplex 10-inch suction 8-inch discharge pump set up on the river bank at the north end of the bridge. The pump was operated by an old locomotive boiler of about 100 h. p. capacity and the water pressure was maintained at about 200 lbs. per sq. in.

The caisson was constructed to a height of about 10 feet; the forms removed and sinking began additional sections 8 to 10 feet

high being added as the sinking progressed. The same forms were used 5 or 6 times and were made of wood.

At the time the sinking of the caisson for pier No. 5, or rather the north abutment, had progressed to within 6 or 7 feet from rock, a strata of very hard, somewhat cemented sand was encountered which offered considerable resistance to sinking, as it would

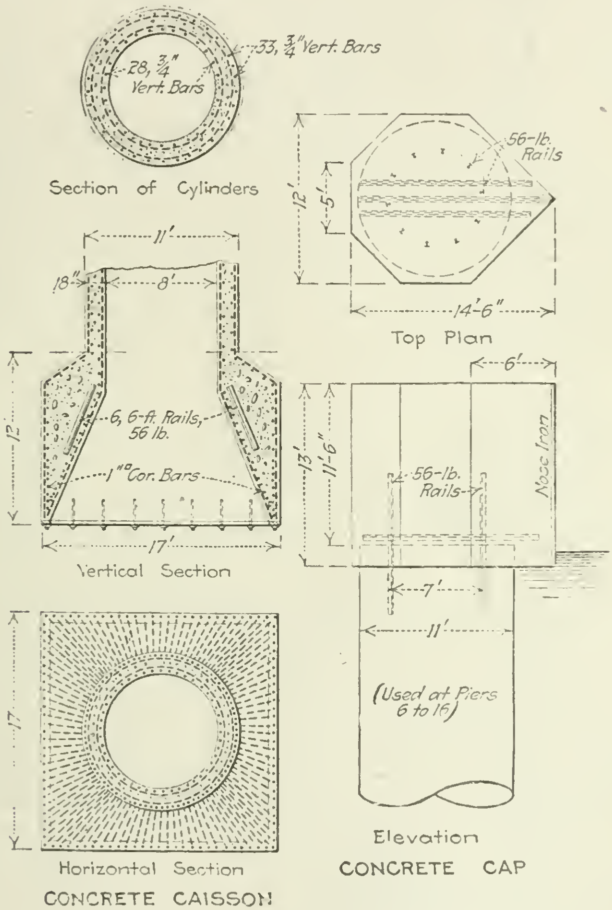

Fig. 11

not flow away from under the cutting edge even when the center of the caisson was excavated considerable below the cutting edge.

The caisson was finally landed on rock after sand boxes containing a large amount of sand had been added to the top of the caisson, a trench from five to six feet deep excavated along the entire perimeter of the caisson, the hard strata broken up by ex-

ploding several half sticks of dynamite at various points in the bottom of the caisson, the skin friction reduced by jetting and enough water pumped out to allow the material under the cutting edge to flow into the caisson.

Figure 11 shows a design of caisson especially adapted for deep foundation work. The pressures used in designing this kind of a caisson are the same as previously mentioned, and for deep caissons amounts to considerable per square foot. It may at the first glance seem that it would not be necessary to design for hydrostatic pressure in addition to the usual earth pressure, but one must remember that the caisson, after it has been sunk to its final elevation, is sealed with only a few feet of concrete, and after this has set, the caisson is pumped dry, and the remainder of the core filled with concrete. With this in mind, it will readily be seen that it is the proper thing to do. Furthermore, the fill against the caisson wall is a loose one, giving a maximum chance for large pressures to be developed. The circumferential steel in the circular shaft would not be required if we were sure of equal distribution of pressure along the entire circumference of the shaft. This, however, is a little too much to expect, there being a good many ways in which the equilibrium may be disturbed, such as cave-ins in the loose ground, boulders, scour taking place on the up stream half, or floating articles, such as logs, striking the shaft. Caissons of this type, like the ones already discussed, can be built on artificial islands or on falsework, and lowered in place by the use of lowering screws. In some cases it may be economical to build a cofferdam, pump the water out and start the caisson on the inside.

The reason for the enlarged rectangular-shaped bottom section is to give larger bearing area and to reduce skin friction. Experience shows that this is a very effective way of doing both. Some fear was felt, when the first caisson of this design was being built, that the steering of this type of a caisson would be hard. This, however, proved to be erroneous, and rather the opposite is true. The railroad rails shown embedded near the top of what may be called the working chamber, are placed there to protect the concrete from excessive abrasion, due to the bucket rubbing against the sides of the working chamber. The shaft is built up in successive sections poured in place. In this case the sections were 13 feet, but this can be varied to any length desired.

The caisson just described was one of several sunk in the Platte river, near Ashland, Neb.; several circular steel caissons were also sunk for this bridge. These will be described later.

This bridge is located on the C., B. & Q. R. R. Co. main line, between Chicago and Lincoln, Neb. At the latter town the main line divides into two main lines, one going to Denver, Colo., and carrying all the California traffic, while the other continues on to Billings, Mont., and carries the traffic from the far Northwest.

The old bridge consisted of 28 deck plate girder spans with

open floor, resting on pile piers, protected by rock-filled cribs. The cribs were built of oak timbers with boiler iron protection.

During the high water in the spring or 1912, an ice gorge formed at the bridge, causing the riverbed to scour to such a depth at one point as to undermine one of the pile piers, and wash it out. Fortunately, the girders which it supported were not dropped into the river, but were held up over the opening by the ends of the girders wedging against each other. Temporary repairs were soon made, and rebuilding in permanent form started. The new bridge is also of the plate girder type, but has an entire new set of piers, and a concrete ballasted deck in place of the old open floor.

A peculiar characteristic of the Platte river is, that it invariably has adjoining one bank a main channel, and against the other bank a secondary channel. These two channels are from one-quarter to one-half mile apart, with stretches of extremely shallow water and sand bars between. The banks are low and very seldom overflow except at times of ice gorges in the early spring. The fall is great and the current rapid, and during high water the amount of silt carried is considerable. The sand is rather heavy, although not so heavy as to prevent its being readily scoured when the stream is confined.

For this reason it has been found better practice to narrow the stream as much as prudence will permit, causing the channel to scour, providing at the time of the spring breakup wider and deeper channels for the passage of the very heavy ice which often forms, and reducing the width of the sand bars between the channels to the minimum. These characteristics determined the design of this bridge in a large measure.

On account of the characteristics stated above, the channel piers were carried only to a stratum of coarse sand or fine gravel, which has demonstrated its bearing power.

Before beginning construction of the permanent bridge, new timber piers were driven 14 feet downstream from the permanent alignment of the bridge.

The new substructure consisted of 20 new piers, so located as to miss the old piers. Caissons for piers 6 to 16, inclusive, and pier 18 were made of reinforced concrete as shown in Fig. 11. All forms for moulding these caissons were of wood, and so constructed that they could be removed and used again.

The excavation was made with a clamshell bucket operated from a track derrick on the temporary bridge, or from a stiff-leg derrick and hoist, the latter being used wherever possible. After the removal of each five or eight cubic yards of sand a ½-lb. stick of 40% dynamite was exploded in the excavated pit. By this method it was possible to prevent the sand from rushing into the working-chamber; and it seemed also to materially help starting the caissons to settle, after a depth had been reached where the skin friction was large.

The perpendicular position of the caissons was maintained by regulating the excavation in the bottom, and by the use of shores against the outside of the shaft. At times it was necessary to employ a diver to remove rocks, boulders, and logs from under the cutting edges.

The excavation was usually from 3 to 4 feet below the cutting edge before the caissons would settle. In founding the caisson on the rock the last 3 or 4 feet of sinking was done by lowering the water in the caisson, thereby causing the sand to be washed in under the cutting edge, and permitting the caisson to settle by its own weight to within a few inches of bedrock. The small amount of sand around the cutting edges which could not be removed was then thoroughly grouted with cement, applied through a 2-inch steam jet. The bottom was then sealed with a 5-foot course of 1:2:4 concrete placed in the water by a ¾-yd. drop-bottom bucket. After this had set for 12 hours, a second course was placed, making a total of from 10 to 14 feet of concrete in the bottom of the caisson. This was allowed to set 24 hours before the caissons were unwatered. After the caissons had been unwatered they were filled with 1:3:6 concrete. The piers were completed to proper height by placing reinforced concrete caps on top of the caissons, and anchored to them as shown in Fig. 11.

With a track derrick using 1 yd. Browning orange-peel bucket, a maximum of 6 ft. was sunk in 10 hours: with the stiff-leg derrick and hoisting engine rig, a maximum of 10 ft. in 10 hours was made. The loss of time with the track derrick on account of traffic amounted to 25%. All the concrete caissons except two were started on artificial islands constructed as follows: a diversion dam consisting of brush and rock was placed in the shallow water just above the pier site. In the still water back of this dam a wooden cofferdam 24 ft. square, and from 4 to 6 ft. deep was constructed, and filled with sand, on which forms for the base of the caisson were erected. After sinking the caisson from 10 to 12 ft. the cofferdam was removed and re-used for the next pier.

At pier No. 11 the water was 12 ft. deep. Here the caisson was constructed on a suspended platform, and lowered into place by means of six 2½-inch screws 24 ft. long. The platform was supported from two 60 ft. girders placed 13 feet centers on pony bents set on the old bridge piers. The weight of the caisson was about 125 tons.

Pier 18, which was the last to be completed, presented many difficulties, owing to the fact that an old oak crib filled with rip-rap and sheeted with boiler iron on the upstream end, had tipped over and settled somewhat below the riverbed. Here a sheet pile cofferdam 19 feet square was driven after the proposed line of the cofferdam sides had been sufficiently cleared of debris. The clearing was done by drilling holes 18 inches apart, with a Davis Calyx core drill and exploding from 5 to 15 lbs. of 60% dynamite in each hole.

Upon completion of the driving of the cofferdam the debris

was removed by the use of dynamite, divers, dredge buckets and sand pumps. When this work had been completed the cofferdam was filled with sand from the riverbed to a little above the water level, the forms for the caissons placed and concreted. Thereafter the work progressed without interruption.

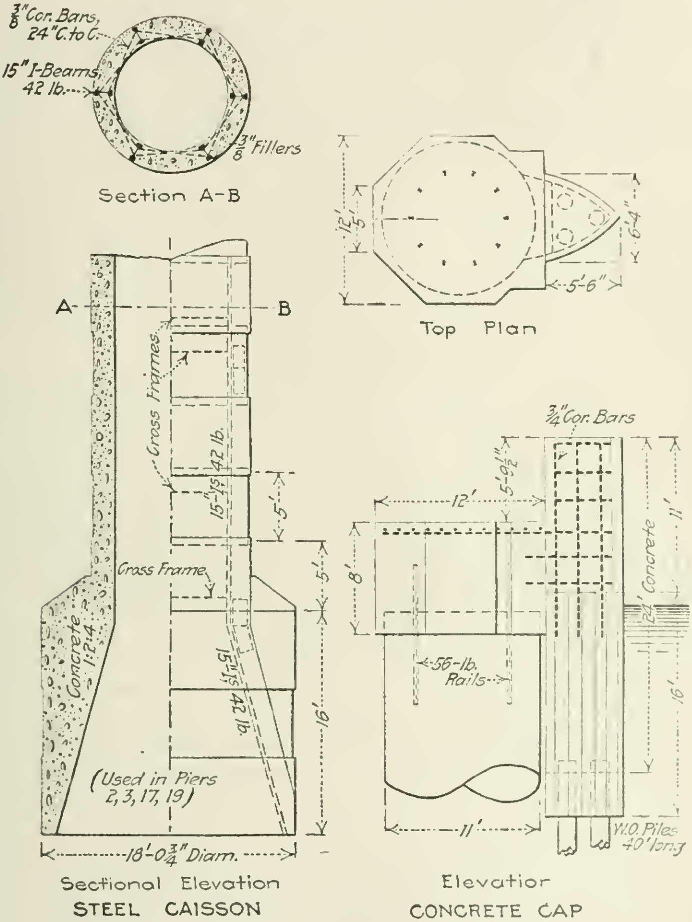

Fig. 12

At the remaining four piers steel caissons were used (see Fig. 12) instead of concrete caissons. These caissons had steel shafts 11 ft. in diameter with the bottom sections or working chambers enlarged to 18 feet in diameter. In each shaft six lines of 15-inch 42-lb. I-beams were run vertically, to which the outside steel plates were

fastened; in the enlarged section 12 I-beams were used. The steel shells were concreted before sinking was started. The shafts were lined with 18 inches of concrete, leaving an 8-ft. well through which the dredging was done. The method of sinking was similar to that described for the concrete caissons.

It was originally planned to use all steel caissons, but the high cost of this construction led to the design of the concrete caissons.

The next bridge at which caissons of this type were used also crossed the Platte River. This bridge is near Yutan, Neb., and located about 12 miles upstream from the bridge first described. Here eight concrete caissons were sunk. The method of procedure at this bridge was the same as that already described.

Test borings taken some time before the construction of the bridge was started indicated loose sand to a depth of 27 feet below the water surface, then a 2-foot stratum of clay, under which was 9 feet of hard white sand or sandstone. Underlying this was a yellow sandstone, into which the caissons were to be sunk about 5 feet.

Piers 6 and 7 were sunk first. The rate of sinking in the sand was 10 to 13 feet per 10-hour shift. After the caisson had settled on the clay the excavation was carried down 10 feet below the cutting edge, without securing any further settlement of the caisson. Owing to the flaring base, it was impossible to excavate close to the cutting edge with the dredge buckets. Various means having been employed to break up the sandstone under the cutting edges without success it was then decided to use the pneumatic process to complete the sinking. The air shaft was connected to a timber roof, made out of 8 x 16-inch timbers laid on the sides and fastened with ⅞-inch bolts to four 8x16-inch timbers set on edge. The circumference of the roof was padded with oakum and covered with burlap to take up any irregularities of surface in the caisson wall. The roof was then lowered to just above the top of the flare in the caisson, and held in place by rods supported on railroad rails placed on top of the shaft. The shaft was next sealed with from 3 to 5 feet of concrete placed under water. When this had set, the shaft was unwatered and concrete placed to a depth of 10 feet. This, by the way, was the top of the first section of steel shaft; from this point up the steel shaft was boxed in, and upon completion of the caissons it was removed. No trouble was experienced in landing the caissons at the desired depth after the pneumatic process was employed. The cost to change this type of caisson from the open dredging method to the pneumatic method is very small.

Most of the designs of the work mentioned in this paper were executed under the direction of the late Mr. C. H. Cartlidge, who was then Bridge Engineer of the C., B. & Q. R. R.

DISCUSSION

The Chairman, Mr. G. A. Haggander, M. W. S. E.: At the Platte River bridge, Yutan, Nebraska, we struck clay on top of the rock and we thought if we sank a caisson down to the clay that we could seal it and get into the rock by open excavation. The clay was so hard that we could not get a tight joint between the cutting edge of the caisson and the clay, and every time we tried to pump it out water would break in. There was no way to stop it because there was such a big bed of sand on top of the clay, and we could not get under the cutting edges on account of the shape of the caisson. We had to give up the open dredging method and use the pneumatic method.

The Kansas City bridge was a case where we either had to use concrete open dredging caissons or a wooden caisson with the pneumatic process. Some of these caissons were sunk about fifty to sixty-five feet below the water line. There were five in this bridge and the deepest one was, I think, sixty-five feet below the water. We compared estimates between the open dredging caisson and the pneumatic caisson. The open dredging caissons proved to be cheaper, and of course the advantage of a concrete caisson for that kind of a pier is in the weight that you get. On the deep one we found that we did not have enough weight to sink it, and we had to put sand boxes on to get the additional weight. We were just barely working within the limit necessary to overcome the skin friction, something like four hundred pounds a square foot.

In general these caissons are adapted to foundations on rock which does not have enough material overlying it to hold the sheet piling. If you have bare rock it is hard to put a sheet pile cofferdam in and hold it, but if you sink one of these caissons you can backfill around it with some impervious material, pump it out and start excavating.

These caissons are also adapted to foundations in sand which contains a good deal of water and is hard to pump dry. They can be sunk right through the sand and water by using pumps, and when down to the elevation desired foundation piles can be driven and a concrete seal placed around them. The caisson can then be pumped out and the piles cut off. From then on the rest of the concrete work can be placed in the dry. By this method one is sure that the piles are embedded in good, firm concrete. It also saves the cost of pumping almost entirely.

In excavating some sand will come in from the outside. The best way to prevent this is to shoot a little dynamite in the working chamber. It seems to give a sudden jar to the caisson and it settles before much sand comes in.

In some caissons a jet was used. In some cases we worked down around the outside of the caisson, and in some cases on the

inside of the caisson, to take the sand away from the cutting edges and bring it toward the center.

When sinking a caisson of this type through gravel it requires a great deal of pumping to keep the water out.

In building the cylindrical caissons we took down the forms in sections and set them up with a derrick. We used the same forms for the entire pier, and afterwards used them on other piers.

Where the rock foundation was not level, as in the Kansas City Bridge Piers, the caissons were sunk until the entire bottom surfaces rested on bed rock.

The rectangular portion of the pier shown in Figure 12 was designed to get a little more bearing for the girders. We had to build out a little to get the bearings, this being a very wide pier.

This method of pier construction has been used for a good many years in other forms than reinforced concrete, and this is probably not the first use with reinforced concrete. I have heard of brick wells being sunk by this method to a good many feet in depth. As to limit of depth, we have gone about seventy-five feet below the water level in some cases, although open dredging caissons have been sunk as deep as one hundred fifty or seventy-five feet.

Mr. J. W. Pearl, M. W. S. E: I believe that method of sinking piers is about forty or fifty years old, and was originally called Cushing's Pier System. In that case they used cast iron.

About 1893 I put a brick well down on land, but I used a reinforced concrete cutting edge. I simply started out and dug a big circular trench, put in some iron and poured in concrete. That well was twenty-four feet in diameter and twenty-four feet deep. It was for a water works. Now a great many water supply wells around the country are sunk by this method, and have been for twenty-five years or possibly longer. I think that the cost of those, under ordinary conditions, will run about thirty or forty cents a cubic foot. Some of them will go below twenty. I had occasion to put one down in Iowa for an intake well for the water supply of an electric light plant. The main supplying the plant was located about twenty-six feet away, and a rupture in that main would put the plant out of commission. We succeeded in getting the well down, but it was accomplished by surrounding the caisson with sheet piling prior to commencing the excavation. This piling was afterwards pulled out. We painted this piling prior to putting it down, with linseed oil, and we found it a good investment, because where we did have cases of settlement and binding of the sheet piling, it reduced the friction. When it came to pulling up, we found it could be done with ease.

There is no difficulty in going through gravel unless it is

cemented gravel. There might be some trouble breaking this up, but it can be done with a small charge of dynamite or with a strong jet.

Mr. Wm. Artingstall, M. W. S. E.: With regard to using these piers, it would be of interest to look through the Proceedings of the Institute of Civil Engineers, especially some years ago, where there are descriptions of the wonderful bridges being constructed in India. There were a series of these written about 1900. At that time they spoke about putting down some of these piers of cut stone, and I believe one of them went down about one hundred and sixty feet.

Mr. Irwin: The Poughkeepsie Bridge piers are one hundred and eighty-six feet below the surface of the water, and they were built by the open dredging method.

Skin friction can be reduced by giving the concrete surface the proper finish.

Mr. W. S. Lacher, ASSOC. W. S. E.: I understand that a caisson of this kind requires that you have some dry land to start with. You must have in some cases a little cofferdam or an artificial sandbar. With a timber caisson is it not possible to build it at some convenient point, float it to place and then sink it? In other words, is there not a limitation to the use of the concrete caisson?

The Chairman: Yes, the field is limited. In our work we probably do not use these caissons on ten per cent of our foundations. In certain cases we think there is quite an advantage. We try to figure out the economy of the proposition between the use of the steel sheet piles or wooden sheet piles or this kind of a caisson. We find in a great many cases the cofferdam method is by far the cheapest.

Mr. W. J. Parsons, M. W. S. E.: The speaker said that this method has been used in a great many instances on different kinds of work. I would like to tell you how I have used this method on pier foundations at Gary, Indiana, which shows how this method comes into play. We put down eight pit foundations for riveting machines, and in Gary the sand is very fine, almost like quicksand. The pit foundations were sixteen feet square, as I remember it, with about four-foot walls on the sides, to give an eight-foot opening for the machines. We had to go sixteen feet below lake level. We tried to put the first one down with sheet piling and it was almost an utter failure because we could not keep it pumped out. The sand would flow in as fast as we pumped it out. Then we tried this open dredging method, made a cutting edge of about 45 degrees on the lower section, which was a six-foot section. We dredged out from underneath and put other six-foot sections on top until we got our desired depth. Then, before we sealed the bottom, we dredged out the wells so that we had a sort of a concave surface. We then sealed the bottom and pumped the water out, and that gave

us our pit. We put down seven of these in various places. We could put down a section in two days. After doing that we put down two wells, twenty-five feet in diameter, fifty feet down in the sand. They were quite a success, and the only trouble we had was that the ground around the outside would give way, and with other foundations near these foundations we had hard work keeping them from going into the hole. Otherwise it was almost an ideal way of putting down the foundation in a sandy soil below the water level. By painting the outside with a tar solution we were able to keep those pits dry sixteen feet below lake level in that sand, which was quite an accomplishment. I agree with the speaker that it is a system that can be used in a great many different ways.

DISCUSSION BY LETTER

Mr. F. R. Sweeny: The skin friction which may develop in the caisson sinking operation, and which influences largely the thickness of the walls, is a surprisingly doubtful quantity. It may be said that this is practically the only force which must be overcome, as the cutting edge offers little or no resistance when considered in comparison with the skin friction, unless cemented gravel, hardpan, or some such other hard material is encountered. Skin friction may be taken at five hundred pounds per square foot as an average, but there are conditions beyond the control of the designer, as well as impossible for him to foresee, that may greatly increase this figure. It is wise to consider these conditions as probabilities and thus secure a great enough sinking weight in the first place, rather than have to resort to loading the caisson later. It seldom costs more to make the caisson heavier to start with, as the dredging wells are filled in solid with concrete in the end.

When the caisson is of considerable height, necessitating a number of "build-ups" it is often the case that they are not maintained exactly in line with each other, and as a matter of fact, if the caisson is a little out of plumb at the time of the build-up, it takes a pretty good foreman to maintain alignment of the two sections. It is obvious that should misalignment be the case, the sinking friction may amount to an enormous value, being in a measure proportional to the error in alignment. Thus is seen the wisdom of designing for all the sinking weight possible.

Experience has shown that building the walls with a batter is not only of no particular advantage in reducing the sinking friction, but it is positively detrimental to the proper guiding of the caisson. It is considered the best practice to have a perfectly plumb wall.

When the depth of water will permit, it is generally cheaper to build up a river caisson on shore, in the form of a wooden shell, launch it, tow it into position between guide piles, and sink it by filling with concrete. Of course, the timber remains in place, but

it is wet continually and, therefore, is not subject to decay. There is no objection to this small amount of timber remaining in place.

The cutting edge may be successfully made of timber where the nature of the materials encountered permit. However, the cutting edge is a vital part of the caisson and it will usually pay to use some kind of a steel cutting edge, not necessarily of a complicated built-up section. The cost is a small part of the total cost of the caisson and much may depend upon it. There are cases where boulders were encountered and the wedging action pushed in the cutting edge, necessitating great expense in repairs. This is more vital in dredging than in pneumatic work, as the latter is subject to inspection at all times.

ADVANTAGES OF HIGH PRESSURE AND SUPER-HEAT AS AFFECTING STEAM PLANT EFFICIENCY

By Eskil Berg.*

Presented June 17, 1918.

The advantages of the steam turbine as a prime mover are today too well known to need much discussion. It is, however, interesting to note that in the early stages of the development, when the thermodynamic efficiency was only about 50 or 60 per cent, it still had such great advantages over its competitor, the reciprocating engine, that it rapidly began to take its place. The chief reason for this is, of course, that outside of its mechanical advantages of simple rotation, it could advantageously use steam at the lower pressure ranges, and a vacuum of 28½ in. or higher is now called for as standard by larger central stations.

The development of the steam turbine has advanced very rapidly, the designer has constantly had higher efficiency in view, and has in this respect succeeded so that today turbines are in operation that are giving a thermodynamic efficiency of almost 90 per cent. While in the future this already high efficiency may be improved by a small percentage, we will have to look to other features of the power plant for further gains in fuel economy. Such gains can be made by increasing the temperature range of the steam, but as the lower range is fixed by the temperature of the cooling water, the gain must be made by going to a higher temperature in the beginning of the cycle, which can be done either by the use of higher steam pressure or by the application of superheat. It will be shown later that a combination of both will give the best result.

EFFICIENCY OF A TURBINE

The thermodynamic or Rankine cycle efficiency of a turbine is the ratio of the mechanical energy taken out of the steam by the turbine to the total energy in the supplied steam when this steam is expanded adiabatically from the pressure at the throttle valve to the exhaust pressure in the turbine casing. (Adiabatic expansion takes place when the lowering of the temperature of the steam is done entirely by extraction of work from the steam.)

The steam consumption of a turbine when connected to an electric generator is generally stated in pounds of steam per kilowatt-hour, and is the amount of steam required to deliver one kilowatt of electrical energy for one hour.

"Theoretical water rate" is a term generally used in all turbine

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investigations, and is the ratio of one kilowatt-hour expressed in foot-pounds (2,654,000) to the available energy in one pound of steam expressed in foot-pounds. The ratio, therefore, between the theoretical water rate and the actual measured water rate gives the efficiency. When the turbine is connected to an electric generator the combined efficiency of turbine and generator is generally given.

FORMULA FOR CALCULATION OF AVAILABLE ENERGY

The formula for calculating the available energy of steam expressed in foot-pounds, either dry or superheated, when expanding adiabatically to any back pressure, is seldom found in handbooks or textbooks, and when such formulæ are found they are rather complex and difficult to use. The formulæ can, however, be made very simple when expressed as the difference between the total heat input and the heat left in the liquid, together with the latent heat in the mixture at the lower pressure. The formulæ then becomes:

$$\text{Available energy in ft.-lb.} = 778\ [H_1 + C_p t_1 - (q_2 + x_2 r_2)]$$

Where H_1 = total heat of saturated steam at initial pressure p_1
C_p = specific heat of superheated steam
t_1 = deg. fahr. superheat at pressure p_1
q_2 = heat of the liquid at lower pressure p_2
x_2 = quality of the steam at pressure p_2
r_2 = latent heat at pressure p_2.

All of these quantities are found in any steam table except x_2 (dryness factor), which is, however, easily calculated from the fact that the entropy is constant before and after the expansion.

Entropy of superheated steam is:

$$C_p \log_e \frac{T_1 + t_1}{T_1} + \frac{r_1}{T_1} + \phi_1$$

Entropy of moist steam is:

$$\frac{X_2\, r_2}{T_2} + \phi_2$$

By making these equal and solving for x_2 there results:

$$x_2 = \frac{T_2}{r_2}\left(C_p \log_e \frac{T_1 + t_1}{T_1} + \frac{r_1}{T_1} + \phi_1 - \phi_2 \right)$$

T_1 = absolute temperature at pressure p_1
T_2 = absolute temperature at pressure p_2
ϕ_1 = entropy of water at pressure p_1
ϕ_2 = entropy of water at pressure p_2

Example. Find the available energy of one pound of steam when expanding from 250 lb. gage pressure, with 250 deg. superheat, to 29 in. vacuum (0.5 lb. abs.).

$$\text{Available energy} = 778\ [H_1 + C_p t_1 - (q_2 + x r_2)]$$
$$H_1 = 1202.3$$
$$C_p = 0.553$$
$$t_1 = 250$$
$$q_2 = 48$$
$$r_2 = 1046.7$$

$$x_2 = \frac{T_2}{r_2}\left(C_p \log_e \frac{T_1 + t_1}{T_1} + \frac{r_1}{T_1} + \phi_1 - \phi_2\right)$$

$$T_1 = 461 + 406.2 = 867.2$$
$$t_1 = 250$$
$$r_1 = 821.6$$
$$\phi = 0.5739$$
$$r_2 = 1046.7$$
$$T_2 = 461 + 80 = 541$$
$$\phi_2 = 0.0932$$

$$x_2 = \frac{541}{1046.7}\left(0.553 \log \frac{1117.2}{867.2} + \frac{821.6}{867.2} + 0.5739 - 0.0932\right)$$

$$= \frac{541}{1046.7}\left(0.553 \times 0.2546 + 0.947 + 5739 - 0.0932\right)$$

$0.5168 \times 1.5685 = 0.812$
Dryness factor $= 0.812$
Available energy $=$
$778\ [1202.3 + 0.553 \times 250 - (48 + 0.812 \times 1046.7)] = 778 \times 444.3 = 346{,}000$ ft.-lb.
[Theoretical water rate per kw.-hr. $= 2{,}654{,}000 / 346{,}000 = 7.67$ lb.]

GAIN BY THE USE OF HIGH STEAM PRESSURE

It has long been recognized that a very large saving in fuel could be obtained by the use of high steam pressure. As early as 1897 DeLaval in Sweden supplied all the power for lighting the Exposition of Arts and Industries in Stockholm with his turbo-generating sets operated from boilers of his own design, using over 1500 lb. pressure. The units used were naturally small, four of them having 100 hp. each and two of them 50 hp. each.

Boiler manufacturers in this country are today prepared to build boilers for 350 lb. pressure and see no difficulties in going to 500 lb. or even higher.

The theoretical gain due to the use of high steam pressure is plainly illustrated in Table 1, in which case 1 lb. of dry steam at 200 lb. pressure expanded to $28\frac{1}{2}$ in. of vacuum is considered unity. It will be seen that by raising the boiler pressure to only 500 lb., there is a saving in fuel of 14.43 per cent. In money this

TABLE 1 THEORETICAL GAIN DUE TO THE USE OF HIGH STEAM PRESSURE

Absolute pressure, lb.	Corresponding temperature, deg. fahr.	Total heat	Increase in total heat, per cent	Available energy in ft.-lb. expanding to 28.5 in. vacuum	Increase of available energy, per cent	Net gain in fuel, per cent
200	381.9	1198.5	....	272,000	....	....
300	417.5	1201.9	0.28	293,000	7.72	7.44
400	444.8	1202.5	0.33	304,500	11.95	11.62
500	467.2	1201.7	0.27	312,000	14.7	14.43
600	486.5	1199.8	0.11	319,000	17.2	17.09
700	503.4	1197.4	0.902	323,000	18.7	18.79
800	518.5	1194.4	—0.342	327,000	20.2	20.54
900	532.3	1191.1	—0.617	329,000	20.9	21.51
1000	545.0	1187.6	—0.909	331,000	21.7	22.6

saving would amount to about $200,000 a year in a plant burning about 900 tons a day with coal at $5 a ton.

THEORETICAL GAIN BY SUPERHEAT

The theoretical gain by superheat is shown by Table 2, which is calculated on the basis of an initial pressure of 250 lb. gage expanded to a 29 in. vacuum. It will be seen that this gain is very small, being only 2.9 per cent when superheating up to 300 deg.

PRACTICAL GAIN BY SUPERHEAT

The practical gain by the use of superheat is often expressed by saying that the water rate is reduced 1 per cent for a certain number of degrees of superheat. The amount of this decrease varies with turbines of different design, but a figure frequently used is 1 per cent gain in water rate for every 12.5 deg. of superheat. Column 5, Table 2, is based upon this assumption.

The actual net gain of fuel in per cent is therefore shown by column 8, which is the difference between column 7 and column 4. It will there be seen that the practical gain by superheat is about two and a half times as great as the theoretical. The reason for

this large practical gain is that in a well-designed turbine of, say, the impulse type, the magnitude of the total losses is made up in about the following proportions when dry initial steam is used:

	Per Cent
Loss due to friction in nozzles and blades and windage loss of disks and blades	20
Leakage loss	3
Rejected energy (due to residual steam velocity)	3
Bearings, packings, etc	1
Total losses	27
Efficiency of turbine	73

It will be seen that the first item is by far the most important one, and it is this item which is reduced by the use of superheat. The use of 200 deg. superheat will reduce the friction and windage

TABLE 2 THEORETICAL GAIN DUE TO THE USE OF SUPERHEAT

Degrees superheat	Temp., deg. fahr.	Total available energy per lb. of steam	Total B.t.u. per lb.	Per cent increase in coal to produce superheat	Per cent increase available to superheat.	Net theoretical gain, per cent	Actual gain, per cent	Actual net gain, per cent
(1)		(2)	(3)	(4)	(5)	(6)=(5—4)	(7)	(8)=(7—4)
0	406	298,000	1202.3	....	....	....	..	....
50	456	308,500	1237.0	2.89	3.53	0.64	4	1.11
100	506	318,000	1264.6	5.18	6.72	1.54	8	2.82
150	556	327,500	1290.5	7.33	9.90	2.57	12	4.67
200	606	336,000	1315.6	9.45	12.75	3.30	16	6.55
250	656	341,500	1340.5	11.50	14.60	3.10	20	8.50
300	706	347,000	1365.3	13.55	16.45	2.90	24	10.45

loss about one-quarter or to 15 per cent, and the total loss would then be 22 per cent, making the turbine efficiency 78 per cent. This reduction is effected by the superheat reducing the moisture in all the stages. The reduction is best shown by the entropy-temperature diagram, Fig. 1. From this diagram it will be seen that starting with steam initially dry at 265 lb. absolute pressure and expanding it adiabatically to 29 in. vacuum through a turbine of 100 per cent efficiency, would result in steam of about 26.5 per cent moisture, whereas if the steam had been superheated to say 250 deg., this moisture would be reduced to about 19 per cent, a reduction of

almost 30 per cent. In an actual turbine this percentage of moisture is of course a great deal lower, depending upon the efficiency.

Table 3 gives approximately the condition of the steam in all the stages of a ten-stage turbine, assuming the turbine has 80 per cent efficiency, is supplied with steam at 250 lb. gage pressure, 250 deg. superheat, and is exhausting into 29 in. vacuum. For comparison the last column of the table gives the steam condition in this turbine had the steam been initially dry.

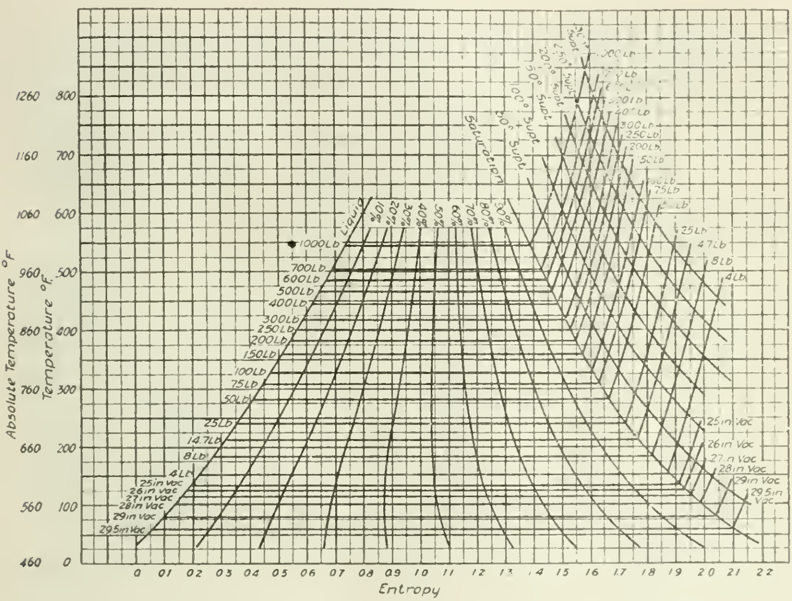


Fig. 1—Entropy-Temperature Curves

EFFECT OF MOISTURE ON FRICTION

A great many formulæ and curves are given by various authors based upon experimental and theoretical data for calculating the friction losses, and they all have a constant which varies according to the conditions of the steam. Professor Moyer, for example, in his book on steam turbines gives a formula for rotation losses of buckets and wheel disks in which the constant is as follows:

Superheat, deg.			Per cent moisture		
100	50	0	5	10	20
C = 0.875	0.93	1.00	1.08	1.25	2.00

In other words, the friction loss is twice as great with 20 per cent moisture as it is with dry steam.

EFFECT OF THROTTLING

Throttling of dry steam always produces superheat; and it has often been said for this reason that there is practically no loss due to throttling, which is true as far as heat is concerned. There is, however, a considerable loss of available energy. The amount of superheat obtained by throttling is easily calculated because the

TABLE 3 CONDITION OF STEAM IN THE VARIOUS STAGES OF A 10-STAGE TURBINE

Assumptions: Steam pressure, 250 lb. gage; superheat, 250 deg.; vacuum at exhaust, 29 in.; turbine efficiency, 80 per cent.

Stages	Steam pressure, lb. per sq. in. abs.	Temperature of steam, deg. fahr.	Suprheat, deg.	Per cent moisture	Per cent moisture assuming steam initially dry
Steam chest	265	656	250 •	...	....
1	120	501	160	...	4.40
2	68	421	120	...	6.80
3	48	354	75	...	8.15
4	28	277	30	...	9.80
5	16	216	...	0.6	11.50
6	9	188	...	2.0	13.00
7	4.7	160	...	4.0	14.50
8	2.4	133	...	6.5	16.00
9	1.1	107	...	8.0	17.30
10	0.5	79	...	10.5	18.70

total heat before and after throttling is the same. Assume that steam at 200 lb. absolute pressure is throttled down to 100 lb. absolute pressure:

Total heat of dry steam at 200 lb. abs. = 1198.1

Total heat of dry steam at 100 lb. abs. = 1186.3

Assume that the specific heat of steam is 0.5:

$$1198.1 = 1186.3 + 0.5 \times t_1 = 23.6 \text{ deg.}$$

The available energy, however, assuming that the steam in both cases is expanded to 28.5 in. vacuum, is:

270,800 ft.-lb., with 200 lb. pressure, dry steam.

240,200 ft.-lb. with 100 lb. pressure, 23.6 deg. superheat, or a loss in available energy of about 11 per cent.

GAIN BY THE COMBINED USE OF HIGH STEAM PRESSURE AND SUPERHEAT

High steam pressure with no superheat has the disadvantage, as will be seen by the entropy diagram, of producing more moisture

throughout the turbine, which means more friction. It is therefore advisable to combine high pressure with superheat so as to produce a more efficient turbine.

Figure 2 shows the ratio of available British thermal units in steam to the total heat in the steam, with feedwater at a temperature of 90 deg.

The present practice in power plants in this country is to use, with turbine drive, a steam pressure of 200 lb. gage and about 150

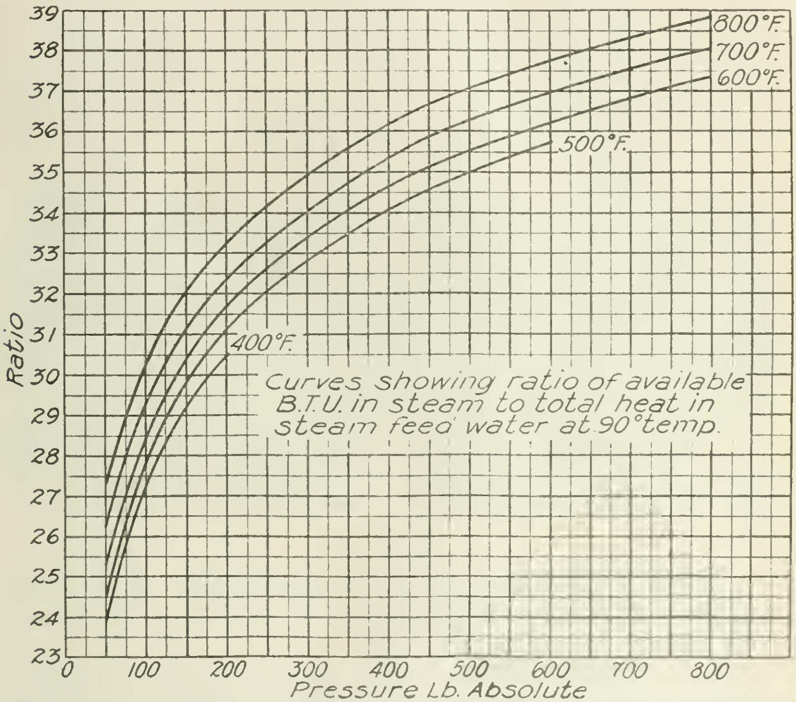


Fig. 2 Curves Showing Ratio of Available B. T. U. in Steam to Total Heat in Steam. Feedwater at 90 Deg. Fahr.

deg. superheat (temperature of 538 deg.), with a vacuum of 28.5 in. From Fig. 2 it will be seen that the ratio of maximum available heat for work to the total heat is only about 31.25 per cent.

Steam temperatures as high as 700 deg. fahr. are now used in Europe, which with a steam pressure of 500 lb. would give 233 deg. superhe... The ratio of available heat for work would then be about 36.3 per cent, or a fuel saving over the above conditions of 16 per cent.

Turbine generator sets are now built having an overall efficiency of over 80 per cent including generator losses, which with

a boiler efficiency of 80 per cent would give an efficiency from fuel amounting to $36.3 \times 0.80 \times 0.80 = 23.25$ per cent. One kilowatt-hour = 3412 B.t.u., therefore the B.t.u. required to produce 1 kw.-hr. at the switchboard = 3412/0.2325 = 14,600.

On the other hand, had 800 lb. pressure and 800 deg. temperature been used, the efficiency would have been 38.75 per cent; and using a turbine efficiency of 85 per cent and a boiler efficiency of 88 per cent (which is obtainable with liquid fuel, forced draft, and preheated combustion air), a kilowatt-hour could be obtained by:

$$38.75 \times 0.88 \times 0.85 = 29 \text{ per cent, or}$$

$$\frac{3412}{0.29} = 11{,}750 \text{ B.t.u., or}$$

$$\frac{11{,}750}{19{,}000} \text{ lb. of fuel oil} = 0.62 \text{ lb.}$$

Diesel-engine advocates now claim a consumption of about .55 lb. of fuel oil per kw.-hr., but with a fuel about 50 per cent higher in price than the grade of fuel which can be satisfactorily burned under a boiler. It will thus be seen that when full advantage has been taken of the various processes that are used in transforming the energy of the fuel into mechanical energy through the medium of steam, the steam process compares quite favorably with results obtained at the present time with internal-combustion engines.

The conservation of our fuel resources is a subject which is being very carefully studied by all power-plant engineers at the present time, and improvements along the lines discussed in this paper are now receiving serious consideration.

CLOSURE

In the discussion following the presentation of this paper a number of questions were propounded which were taken up in order by the author as follows:

Dr. Thurston's remark to the effect that the most efficient all-round superheat would be that which would give dry steam in the exhaust, he said, was correct at the time when moderate steam pressure was used and the efficiency of the prime mover was around 50 per cent. Assuming, however, an efficiency in the prime mover of 80 per cent, 200 lb. steam pressure, and an exhaust pressure of $28\frac{1}{2}$ in. of vacuum, in order to obtain dry steam at the exhaust the superheat would be above 1000 deg. or in a territory practically unknown at the present time.

When the high-pressure boiler was developed, it would, in his opinion, be smaller, lighter, and cheaper per horsepower than the present boilers.

In regard to the question of moisture; for a given turbine efficiency the moisture was, of course, the same as the theoretical. If in practice the moisture was found to be excessive, it must be

caused by the initial condition of the steam, either having less superheat than assumed, or it might be quite wet when entering the turbine.

In reply to the question whether the first 50 deg. of superheat was not more effective than the last 50 deg. of the 200, he would say that it was, because it reduced the moisture in the high-pressure end of the turbine where the friction loss is greatest. Turbine manufacturers recommended 50 deg. of superheat because it was easily obtained and it at least assured them of dry steam at the throttle. Very few boilers gave dry steam in practice.

In regard to high superheat showing a great saving in fuel with reciprocating engines, it was to be remarked that records of several European vessels operating with steam temperatures around 700 deg. showed that the saving in fuel was in some of them as high as 17 per cent and was sufficient to pay for the cost of installing the apparatus for producing superheat in a few trips across the ocean.

As to an inquiry in reference to the durability of packings, etc., at the higher pressures and temperatures, he would say that in all probability no packing would be used in the piping system and all joints would have to be welded. This, however, should not raise any difficulty. The paper has been primarily intended to point out the direction in which it was necessary for all to work in order to improve fuel economy, and to show that the advantages derived by the use of high steam pressure and superheat were infinitely greater than the few practical difficulties which had to be overcome.

THOROUGHFARES

By O. C. Simonds, M. W. S. E.

Presented May 20, 1918

This subject is chosen because it is a very broad term and includes almost every kind of passageway where the public is permitted to travel. With this as a subject I can speak of streets of various kinds as well as country roads. Let us first consider the lines governing the horizontal position of streets. It has been quite customary to make nearly all streets in cities straight and generally running north and south and east and west regardless of the topography. It is not at all essential that they should run in these directions or along straight lines. For practical purposes as well as for a good appearance some variation from such lines is desirable. The Germans, who are at present in very bad repute in general, have nevertheless had some good ideas with regard to city planning and the location of streets. They have maintained that streets laid out on curves or on broken lines display the architecture of the buildings to good advantage and make the streets really interesting and facilitate travel. Diagonal streets, that is those which vary considerably from the cardinal points of the compass, allow all the windows of buildings facing them to receive sunshine at some time during the day. This is certainly an advantage. Diagonal and curved streets frequently shorten distances. The diagonal streets radiating from the central part of a city are sure to become important thoroughfares because they shorten the distance to be traveled. Such diagonal streets should extend into the country to shorten the distance which farmers have to travel in bringing in their produce. For instance, a farmer's house seven miles away measured along rectangular roads might be only five miles away measured along a diagonal.

The intersections of streets should be carefully considered. There are many instances in the older portion of Chicago of a jog at an intersection because the streets of one subdivision have not corresponded with those of the one next to it. If the jog is only a few feet its inconvenience can be relieved somewhat by curving the curb for some distance from the corner. A roadway could thus be made reasonably continuous although the bordering lot lines of one block fail to correspond with those of the next. It would also be an advantage to have the curb at intersections curve on a longer radius than has usually been used. Many automobiles require a space of sixty feet in which to turn. If the radius connecting the curbs of streets meeting at right angles is only three or four feet it is frequently necessary for an automobile in turning the corner to encroach upon the left-hand side of the cross road. If the radius for the curb at intersecting streets was never made less than twenty

feet the obstruction to traffic at intersections would be greatly reduced. This would not inconvenience pedestrians if the levels of the sidewalk and the pavement were made practically the same at the street corners, as they should be. It might be advisable in many instances to have the lot line as well as the curb line curve at the corner of two streets. This would help to relieve the congestion of pedestrians while not interfering seriously with the use of abutting property.

The width of streets has been discussed many times and I will only mention the fact that it is not necessary to have all streets of the same width. The width should correspond with the use to which the street is put. Prominent business streets should in many instances be one hundred feet or more in width. Main thoroughfares connecting neighboring towns should be wide, but side streets, especially those which are short and have no through traffic can be relatively narrow. For a discussion of the width of streets I would refer you to Mr. John W. Alvord's "Report to the Association of Commerce on the Street-paving Problem," and Mr. Charles Mulford Robinson's book on "City Planning."

In the active business portion of a city the features affecting the appearance of the street itself are the pavements, the sidewalks, the street lights and the hydrants. It is taken for granted that overhead wires should be eliminated. In the outlying districts where the residences are located it is usually desirable to have, in addition to the features named, shade trees and areas devoted to grass or other low-growing vegetation. The city engineer of a large city in Michigan said that "trees had no business in any city," but fortunately his view is not shared by many. Trees really make the beauty of a city. The architecture of the buildings may be bad, the houses may be poor, but if the streets are lined with satisfactory shade trees, if elms and maples spread their branches overhead, the general impression given to visitors will be that of a beautiful city. Assuming then that the residence streets will have pavements, planting spaces and sidewalks, their location with regard to each other should be considered. A planting space between the sidewalk and the roadway is generally desirable because this arrangement gives shade to both sidewalk and drive and seems to give a more quiet and safe place for pedestrians. It also places the trees farther from the buildings than they would be if the sidewalk was at the curb or edge of the roadway and the planting next to the lot line. There are varied conditions, however, which would often make the modification of a general rule desirable. For instance, a city in Iowa had an ordinance requiring that sidewalks should be six feet wide, the inner edge of this sidewalk being placed two feet from the lot line. One day when I visited this city a street was being improved by the construction of pavements and sidewalks. This street although only used for residences was one hundred feet wide and the pavement that was being put down was fifty feet

wide, notwithstanding the fact that there was no car line upon it. This left a space for sidewalk and planting of twenty-five feet on each side of the street. Along the front of my client's property within the street area and at a distance of from three to seven feet from the lot line some excellent native bur oaks and hickories were growing. The city authorities wished to take these trees out. I called attention to the fact that many years had been required to produce the trees; that the rule regarding sidewalks might be changed in the block in which these trees were located without harm to any one, the sidewalk being placed, say, at a distance of eight feet from the lot line instead of two; that such an arrangement would still leave eleven feet between the walk and the curb. But the ordinance was held to be a sacred thing and the trees of at least fifty years' growth were cut down. Such vandalism is without any excuse. There ought to be sufficient elasticity to ordinances so that an improvement could be made which complies with what we ordinarily call "common sense."

Many of us have grown up with the idea that trees should be planted in rows, but many of the most beautiful streets I have known have been those in which some of the original native trees have been allowed to remain along the street borders. These followed nature's arrangement of irregularity. One street of this kind was out in River Forest. Along one side of a block in this street I noticed first a spreading thorn apple. Its branches were high enough so that they did not interfere with people passing. Just north of this thorn apple was an old healthy bur-oak, the two trees together forming a very attractive group. At some distance beyond the bur oak was a group of lindens. These two groups of trees made this portion of the street most beautiful and attractive. A photographer with the instincts of an artist would have been glad to use his camera in reproducing them, but a week or two after first seeing them I was passing along this street and noticed that the fine old bur-oak, the thorn apple and the lindens had all been cut down to make room for a row of elms two inches or less in diameter. It would require many years for these elms to produce the shade that was produced by the trees removed and although the elms are the most graceful of our native trees their effect would never equal that of the trees which had been destroyed. There are many roadsides and borders of city and village streets where fine old oaks, elms, maples, lindens and other native forest trees are growing in perfect health. These give dignity and character to the thoroughfares they adorn. There certainly can be no harm in curving a sidewalk to any position between the curb line and the property line for the sake of saving these patriarchs, providing the lines of curvature are long and gentle so that the distance to be traveled is not appreciably lengthened. What harm would there be in occasionally moving the curb line a little so that the roadbed would approach nearer one side of the street than it

is to the other? If a street as a whole is picturesque and attractive value will be added to the lots on both sides. A volume might be written describing the beautiful effects which we might have along our street borders or roadsides by using trees, shrubs and herbaceous plants in picturesque combinations. Such effects are sometimes realized in out-of-the-way country places. If we were sufficiently civilized we might have such ideal roadside beauty all along the city and village streets which are bordered with homes.

You may think that this is getting outside of the domain of engineering, so I will proceed to consider the lines determining the vertical position of roads and walks. In our office we usually like to have street grades fixed between one and six per cent. Occasionally it is necessary to go beyond these limits, making streets either too flat or too steep, but such excesses are avoided where possible. We prefer going around a hill to climbing over it or going through it. Where changes in the grade occur the change should be made by a long gentle curve in the profile. The connection has frequently been made by a very short curve giving the effect of an angle. Such profiles are not pleasing either as drawn on paper or as seen in the actual pavements. I was once surprised and pleased to hear an engineer with whom I was working, a man who had at one time been president of this society, say that he usually drew his profiles by eye. This is really the best way not only to make the curve showing the vertical position but also the curve showing the horizontal position of streets. In practice I like to indicate all curves first on the ground by means of stakes placed at frequent intervals, locating these stakes by eye, testing the vertical curves, however, by a hand-level to see that the usual limit of steepness is not exceeded. If the curve satisfies the eye it does what it is intended to do. Incidentally it may be noted that the arc of a circle is the least pleasing of all curves because of its monotony.

Three sight poles or tees of equal length are useful in determining vertical curves. I have referred to the fact that a sidewalk might without any disadvantage to pedestrians curve between the curb line and the property line even when these lines were straight. The curve showing its profile or vertical position may likewise vary from that of the curb or pavement, especially where there are no drives entering the abutting property. Examples of sidewalks three or four feet higher than the curb may be found in some of the best streets in Evanston. Such variations from strict uniformity or standardization may not only save trees but they preserve the pleasing effects of a varied topography.

In the city where I used to live there was a street a mile and a half long having an undulating profile. During one of my visits to this city I noticed that the high places in this street were being cut down and the low places filled up, causing the rebuilding of sidewalks, the construction of walls to retain the earth in private grounds, or to hold up the road where it passed through hollows.

The owners of abutting property naturally protested, but they were powerless. The chairman of the Board of Public Works said that his idea of a beautiful street was one in which a person could put his head upon the pavement and sight from one end of the street to the other and have the line of sight coincide with the surface of the roadway. I should like to utter a protest against such acts of destruction which are neither in accordance with common sense nor with the ideas of economy or beauty.

In making plans of subdivisions the location of streets should be determined largely by the topography. They should connect the starting point with the destination of travel in the easiest manner possible without destroying the beauty or accessibility of abutting property. There are many places where even country roads should not follow section lines. In England, which by many is considered the most beautiful country in the world, I once traveled over five hundred miles on my bicycle and during the entire distance passed through only ten miles of straight thoroughfares.

While most people will admit that curved streets are more beautiful than straight ones there should always be some reason for the curve. An example of what not to do is found in a village on the Chicago, Burlington and Quincy Railroad. I was told that the originator of this village, a real estate man, went to a surveyor and asked him to lay out a town with curved streets like those of Lake Forest. The surveyor said: "You had better get some one who is familiar with such work to plan your town. I can survey it if I have a plan, but without a plan I would not know that I had the curves right." The real estate man replied, "Oh, you can lay it out well enough," and thereupon he took his compass and described a portion of a circle. Then placing the point of the compass on the other side of this line described an equal arc with reverse curvature and so on to the end of the street, the result being a series of reverses. The village was actually laid out in this manner and some of the streets built. The result was that people would tend to drive first into one side and then into the other side of the street and the village came to be known as Jag Town.

The test of a good curve is the location of the main lines of travel. If these are parallel to the center line of the drive the curve is satisfactory. Curved streets are advisable when they help us to have easy grades, when they shorten distances to be traveled, when they enable us to save beautiful objects, or when they show us attractive views that would not otherwise be seen.

DISCUSSION

Mr. C. B. Burdick, M. W. S. E.: In my recent experience in Porto Rico one of the impressing phases of the visit to the island was to ride over the excellent system of roads in that country. The

island is about thirty-five miles wide north and south and about one hundred miles in length. It rises up from the ocean to an elevation of about four thousand feet. The high ground borders the ocean quite closely, the hills beginning within three or four miles of the coast and, as may be imagined, in rising to four thousand feet in a short distance the road problem has been of very great importance to that country.

The island is decidedly rough—so rough that it has been impracticable to build railroads into the interior. The railroad upon the island skirts the coast and the interior of the island is served entirely by roads. The Spaniards, who were in possession of that country for something like three hundred years, started the road system. They built the main arteries, the military roads that lead from the coast towns back into the hills, and in the old days the interior of the island with its population was served by the freighters, the mule teams and the ox teams that drew the produce from the farms to the ports and drew the American manufactures from the ports to the farms. Since the American occupation the old Spanish system of roads has been very much strengthened. The island now has about eight hundred miles of roads administered by the Insular Government. The roads are very well maintained; in fact, the satisfaction of riding and driving on the Porto Rican roads is as great as on the roads in New York, New England or other parts of the United States. They are almost perfect waterbound macadam roads; oiled in the cities but not oiled in the country districts.

The difficulty of road construction through the mountains are comparable perhaps with the roads of some of our northwestern states, like Colorado, for instance. The roads, necessarily, in rising to the heighth of three thousand feet in the short distance from the coast to the top of the ridges, wind back and forth in order to get grades that are at all practical and it is not unusual to look from a high place and see the roads winding back in loops, six or eight times, in view from one place.

In construction the roads differ only slightly from the waterbound macadam roads in this country. In one respect, however, they differ in that the cross section is somewhat similar to what we know as the "telford," in that the base is constructed of large stones. After the sub-grade is finished they lay a curb. They call it a "moredenti," meaning in Spanish "dead teeth." It looks a good deal like a row of teeth along the curb. Another row is placed in the center and the base course all hand laid between those two lines of heavy stone. The 2 and 3 inch stone is placed over that and they finish it with a thin course of inch stone, and all the work aside from the rolling is done by hand.

The work that I was engaged upon was military work; construction of an army camp for the Porto Rican draft army, and

it was done under conditions that differ quite materially from conditions in the United States. Here we have a dearth of labor and everything possible is done by machinery, but in Porto Rico that is different. Labor is plentiful and cheap, and everything is done by hand. For instance, road construction, as I said a moment ago, is all done by hand, except for the steam roller.

The transportation is very interesting to me. It is not an uncommon sight to see an ox team, a pony cart and a Pierce Arrow motor truck all loading at the same stone pile and we got very good service from the ox teams. In a part of our camp the roads were rather inaccessible during the period of construction. The camp site was quite hilly and sandy. It was impossible to get into the inner territory with trucks and extremely difficult to get in with four or six-horse or mule teams. The most practicable means of getting material into the back of the camp was by two-wheel carts about six feet high, to which were usually hitched two strong oxen; sometimes three, and they were able to get over the sandy ground, and could reach ground that could not be reached in any other way.

Altogether, the Porto Rican experience was very novel and agreeable to an American engineer and the beautiful system of roads in Porto Rico was by no means the least agreeable impression of the visit to that country.

The Chairman: The subject of thoroughfares is a very important one, and it is going to be more important, especially in these days of dense traffic conditions and increased motor travel, both by trucks and pleasure vehicles. Thoroughfares bear, it might be said, the same relation to any general system of roads that the main lines of a railroad bear to the branches and feeders. Thoroughfares, of course, may be through the city or through the country; in fact I may say there are thoroughfares for pedestrians. A sidewalk is certainly part of a thoroughfare. Sometimes we find walks built through parks and public property where it is really a thoroughfare in itself.

M. C. Tobias, A. W. S. E.: One point that Mr. Simonds brought up might possibly be taken up a little farther, and that is the increase in effective width of streets by cutting back the curves at intersections. This necessity has been brought about largely by the use of long coupled motor trucks, having a wheel base of fifteen feet and a tread of seven and a half feet. For instance, a Packard truck having a wheel base of one hundred seventy inches and seven foot tread requires in the neighborhood of a thirty-seven or thirty-eight foot circle for the outer front wheel in turning.

I have recently seen several diagrams showing automobiles going around street intersections in which without fail we have shown two curvel lines which the automobile followed around the corner. That is a point that is lost sight of. An automobile's front and rear wheels do not track. It goes sideways. This is not exactly the condition that we do obtain by what is known as the Ackerman

steering gear, as the two front wheels with the present steering gear are parallel, whereas they should be perpendicular. However, it is hardly noticeable.

An equation has been developed for computing the radius necessary for the outer front wheel when the inside radius of the inside rear wheel is known. We made field tests with a Marmon car having a wheel base of 137 inches and 55-inch tread. We turned this car around on a 13.9 foot inside radius and found that the radius of the outer front wheel was twenty-two feet. Computing it with the formula would give twenty-one and eight tenths feet, which is very close to the actual field test.

This point was recently brought home to me rather emphatically on some industrial roads. We designed a road, and we thought we had it so motor trucks could get around. We started running Packard trucks and we found that they would not stay on a ninety-foot road with a twenty-five foot radius at the corners, and it was necessary to build out the corners with extra concrete to let the trucks get around.

Mr. Eaton: Reference has been made to the zones of safety that are constructed in Chicago. Some time ago attention was called to the frequency of accidents. We made some investigation and gave some thought to the proper design of safeguards. It seems that most of the accidents occurred at night, and while doubtless a large proportion of them may be charged to careless or reckless driving, the fact still remains that these accidents should not occur as often as they do.

A number of lamp-posts in Chicago have been painted white within the last year and that has helped considerably, but I feel that still further improvement may be made if the lanterns are illuminated by white globes or bulbs. It is a matter that I think deserves attention.

B. J. Ashley, M. W. S. E.: There is one feature of considerable interest to me as a driver of machinery and that is the curvatures of the new improved concrete roads; curved more or less abruptly. In going through the country in different directions, from the city, I do not recall having passed around the curve of any newly constructed up-to-date concrete or otherwise paved road in which the necessity for widening the driveway at that curvature has been recognized.

I think I have observed in one or two places where the outside of the improvement was raised, rightly, to a higher elevation, and as I have listened tonight I have wondered whether the state engineer, either past or present, of this state, who is laying out the new concrete roads that we are traveling, is a member of this section or whether in some way information could be gotten to him of the necessity of widening the improved track where these curves exist.

One of the most flagrant misconstructions that I can think

of exists just north of Chicago Heights, where there is a double curve, and I see one or two of you nodding your heads. You know exactly to what I refer. It gets on my nerves every time I drive over those curves, to think that an engineer, under the name of an engineer, could have laid out his work in that way unless he was precluded by some law or some ordinance or something of that description. It that is true, something should be done to obviate the making of these rules. The necessity for a higher grade and the widening of the roads in consequence of passing machines at a curve is so very manifest, it seems as though any good engineer would see it and undertake to design a proper road at these curves.

H. E. Goldberg, M. W. S. E.: On the streets with single and double curves, running in all sorts of directions, how would the numbering system be effected? What kind of a scheme do they use in German and other cities? What percentage would Mr. Simonds say to spend for beauty and what per cent for utility. Also, what is the increased cost of the curvatures of sewer pipes and water pipes, assuming that sewer pipes and water pipes follow the street line and do not go upon the private property? Every now and then we have to put in a curve in a sewer pipe and in water pipes, and also conduits.

Mr. Simonds remarked that the arc of the circle is the least pleasing curve and then again he found fault with the double oblique. I would like to know what kind of a curve, in his mind, is pleasing.

Member: The subject of thoroughfares is a very deep subject and apparently the only phase touched upon tonight is on the dense streets. The matter of layout of streets and widths depends upon a great many factors other than artistic considerations. In Chicago the engineers are limited by ordinance, but a great deal of effort has been spent in the last few years to secure some measure of beauty, some measure of convenience, and some measure of comfort. We have a great many residential streets which I think are somewhat prettier than any views shown tonight. Very few people in Chicago are familiar with Chicago. There are some very beautiful spots in Chicago. Take for instance, Norwood Park. Some of you are familiar with the manner in which that is laid out—in very large sweeping curves.

In recent years it has been a practice in case of sidewalks, in order to save trees, to build the sidewalks maybe two, four, six, eight, or ten feet from the line. It requires in those instances that a special line ordinance be passed. That has been the custom the last few years and in that way we very seldom have to cut down a tree to put in sidewalks in residential districts.

On some of our streets we have made an effort, where the ends of the street abut on the lake or river or places where streets cannot go through, to build the street in the form of a curve and then shrubbery and plants can be planted there.

Reference has been made to the practice of curved streets in European cities. In a city like Chicago, where the traffic is getting to be mostly automobile traffic, you must remember that we have the matters of speed and safety. That enters a new element that did not have to be considered in the old days. People will persist in driving their cars at a pretty good rate of speed.

Mr. Simonds: I think we have a very good numbering system in Chicago, and I believe it can be made to fit almost any line of streets. We have diagonal streets, and we have no difficulty, as far as I know, in applying the numbers to diagonal streets, or curved streets.

With regard to ten per cent beauty or ninety per cent beauty, I think, if we knew enough, we would have one hundred per cent of each. I believe that utility and beauty go together. Take the lines of a horse. They develop from muscular exertion. I think that is almost universal and if we knew enough we would make the things we make both useful and beautiful. Take the lines of a violin. They are beautiful and people who play violins tell me that the violin is adapted to its use; that it has a hollow curve to allow the bow to stand at different angles when the player is playing, and that makes a case of utility and beauty.

Now our curved streets should have some advantage in utility from the curve as well as being more attractive. I always tell people that the curves should shorten distances or accomplish some other useful purpose, but nearly always there is a reason for having a curve in outlying districts.

I think that the sewers should run with the street. Probably there would be a shortening of the total distance due to the curves and cutting of corners. I imagine there would not be very much increase in cost, but many of the streets I have referred to are in the country, where they have no sewerage and it is very easy to take care of the surface water.

Mr. Goldberg: I find a good deal of trouble in Chicago with the diagonal streets. For instance, take Lincoln Avenue on the north side. I always forget whether that street is supposed to run parallel to the north and south street or the east and west street, and I have always been confused in that, and I do not think it is possible to get up a numbering system that will work.

E. S. Nethercut, M. W. S. E.: The problem possibly has been worked out this side of Germany, namely in Washington, where all of those diagonal streets are in evidence and where they have a perfect numerical system of numbering.

The north and south streets have numbers and the east and west streets have letters and frankly, it seems to me that the diagonal streets in Washington are so easily located and the numbers so easily located that I can hardly understand why a question should be raised in the matter.

The statement of Mr. Simonds I think is correct, that the number represents the distance from the intersecting base street.

In Washington it is north and south Capital Street and east and west Capital Street, and in Chicago it is Madison Street and State Street, but you can readily see how the number would indicate actually the distance.

Member: In connection with what has been said, there is a difficulty in the diagonal street. Take Ogden Avenue in Chicago, which starts at sixteen hundred, or about fifteen hundred and yet it is not an east and west street. Now a person who is unfamiliar with that street will look for twelve hundred and will not find it, and he will look for sixteen hundred down towards Sixteenth Street, whereas it is near Madison, and it does make quite a bit of difference unless you know.

Mr. Nethercut: I might explain with regard to Washington that whether the street is numbered by the east and west system or the north and south system is dependent upon the angle of the street. If it is forty-five degrees it is right between the two lines If it is less than forty-five it follows one of the others.

Member: It seems to be the practice of most engineers to super-elevate the other edge of the roadway. Why would it not be a better practice to depress the inside of the curve?

Mr. Eaton: I think that the practice will vary considerably in different states. I think it would give a little better appearance, but other than that I know of no special reason why it should be done.

In New York and Ohio the streets are widened at the turns.

Mr. Ashley: Mr. Chairman, I have suspected that the reason that these curves have not been widened was because the contract had been written that the pavement should be so wide, a certain width and that in consequence of that the roadway engineer has been restricted to building his road according to contract.

Mr. Tobias: According to Mr. Ashley's contention on the widening of curves, I believe one reason for not widening the curves at intersections is that it would entail in a great many instances the buying of land in order to widen the curve, and it is pretty hard to get a State Highway Commission or the County Board of Road Commissioners to buy a strip of land from the farmers for the sake of widening that curve.

Regarding these diagonal streets, I lived in Detroit for quite a while and if any of you gentlemen have been unfortunate enough to have tried to find a number in the City of Detroit you will appreciate diagonal streets in a negative sort of a way. You will find the number that may be thirty-seven hundred on one block, and you think, "Well, I will walk over to the other block and find the same number," and you go over and you will find sixteen hundred.

I remember when I first started working for the Portland Cement Association, some four or five years ago, there were about twenty fellows sent to look over the concrete roads and we congregated in the hotel in the evening and several of the boys had not gotten in. It was in the wee sma' hours of the morning. One

of them came in about one o'clock, and I asked him where he had been. He said, "I've been over there." He did not know where he had been, and I never go to Detroit without getting lost. I certainly believe that some better numbering system than the Detroit system should be gotten up if you are going to have diagonal streets. I believe they start numbering from the courthouse and run out from there.

T. S. Ford, M. W. S. E.: I think it was the intention in the numbering system of Chicago to have all east and west streets called streets and all north and south streets called avenues, courts or places, but only the one name for the one direction. It would be a hardship perhaps for dwellers on a certain street to have it changed from street to avenue, but it seems to me as though it would be a good thing.

DISCUSSION BY LETTER

Mr. R. S. Schuchardt, M. W. S. E.: It is very encouraging to have a paper like Mr. Simonds' presented before the Western Society of Engineers, because it indicates an appreciation on the part of the author that the engineer's work is not always purely technical. Boiled down to its essence, Mr. Simonds' paper, while recognizing that utility is the first thing to be considered, is a plea to get the maximum natural beauty in the lay-out of every street.

The important part that thoroughfares play in the cost of living is little understood. The delays resulting from congestion of traffic add materially to the expense and thereby increase the cost of doing business and the cost of living in a city. This is well brought out in the Chicago Plan Commission's published data with reference to the need for the so-called Michigan Avenue Link Improvement.

The laying out of streets is but a part of the very important subject of city planning, and city planning or replanning has been very well described as municipal conservation.

Unfortunately city planning in this country cannot progress as rapidly as we would like to have it because of the restrictions now on our statute books, and these restrictions will not be removed until an awakened and understanding public opinion demands their removal. Some states have already experienced at least a partial awakening and there are many cities, possibly fifty or sixty, that have been giving considerable study to the problem.

One of these cities is Seattle, Washington. In 1911 a Municipal Plan Commission was created by the city charter to engage city planners and to direct the work to be done by them. It is interesting to note the provisions regarding representation on this commission. There are a total of 21 members, selected as follows:

Three from the City Council.

One from the Board of Public Works.

One from the County Commissioners.

One from the Board of Education.

One from the Seattle Park Commissioners.
One from the Pacific-Northwest Society of Civil Engineers.
One from the Washington State Chapter of the American Institute of Architects.
One from the Seattle Chamber of Commerce.
One from the Seattle Commercial Club.
One from the Seattle Manufacturers' Association.
One from the Seattle Central Labor Council.
One from the Seattle Clearing House Association.
One from the Seattle Bar Association.
One from the Seattle Real Estate Association.
One from the Seattle Carpenters' Union.
One from the Seattle Water Front Owners' Association.
One from the Steam Railway Companies.
One from the Marine Transportation Companies.
One from the Street Railway Companies.

Why the Teamsters' Union was omitted, I do not know. It is interesting to note that the vote on the adoption of a report recommending definite planning was 18 to 3 in favor of such plan, and the three votes were all cast by political appointees on the commission—two from the representatives of the City Council, and one from the County Commissioners.

Pittsburgh, in 1910, feeling the handicap resulting from the very poor physical structure of the city, carried out an investigation under the direction of the Pittsburgh Civic Commission. Mr. Frederick Law Olmsted, the well known landscape architect and city planner, was retained to study the thoroughfares and to propose a program suitable for the next twenty-five years, and at the same time Mr. Bion J. Arnold and Mr. J. P. Fox were asked to study the traction system. Just what has resulted from these studies further than a very interesting report, I do not know. The State of Pennsylvania now has a law which we might well give attention to. This permits the laying out of a street in anticipation of a future need and then to postpone taking possession or opening to the public. The owner of the land covered will receive compensation for his land and for any improvements which may exist thereon at the time the plan for the future street is announced. No compensation, however, will be paid for any improvements made after that date. This law applies also to the widening of existing streets.

The study in Pittsburgh extended beyond the confines of the city, which is of course correct, since the flow of traffic is not limited by the artificial boundaries, and the highway problem cannot be adequately dealt with piecemeal.

Illinois is about to have a Constitutional Convention and our present constitution is on the board for discard. The new constitution should contain all the provisions which will enable us to have cities in which we can really live—not merely exist; and the engineer, because of his special training, ought to be the first to appreciate

the necessity for proper planning and the first to help spread the propaganda for it.

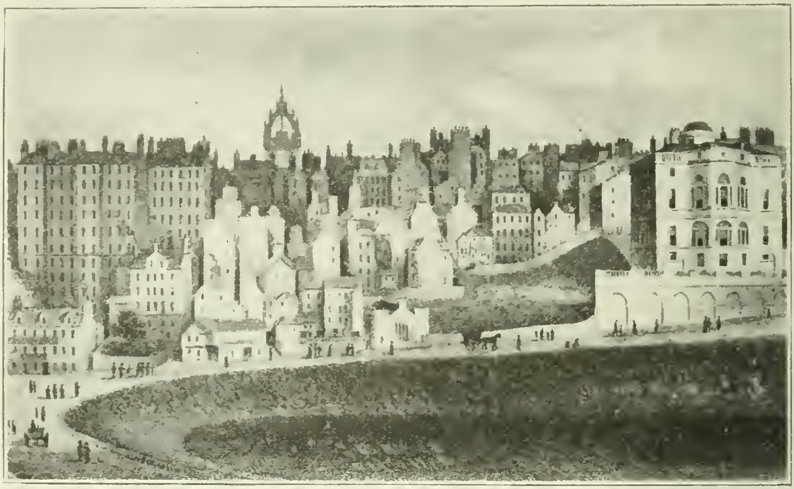
We hear on every hand that "this is the engineer's age," that "engineers are at last being recognized," and because of the many excellent things that the engineers are doing in connection with the war a shower of bouquets is being tossed to them. I wonder if this has not a tendency toward undue self-satisfaction, and if we are not getting "stuck up" over being engineers instead of knuckling down to do our utmost to be worthy engineers and worthy citizens. The United States has a tremendous obligation to fulfill, to make good its cry for making the world safe for democracy. Has not the engineer also a special obligation to help make this democracy a fit one for all to live in and to develop in? Has he not now a natural responsibility to come out of his technical shell and to absorb an understanding of the throbbing world about him, because his special training has given him the ability to understand, and the knowledge, when combined with that of trained men and women in other professions, requisite for the solution of many of these important civic problems?

Will the engineer be equal to this responsibility? Will he successfully meet the obligation?

THE SKYSCRAPER AND BUILDING HEIGHTS IN THE UNITED STATES

By R. Fleming.*

The birthplace of the skyscraper was Edinburgh. The tourist may read in his "Bædeker" that the Old Town is full of interesting old houses, "some of which are remarkable for their immense height (10-12 stories)." In "Modern Athens. Displayed in a Series of Views, or Edinburgh in the Nineteenth Century," dated 1829, a book much prized by collectors on account of its engravings, Shepherd writes of these high houses, "Previous to the commencement of the



Part of the Old Town, Edinburgh. From an engraving made in 1829 for Shepherd's "Modern Athens."

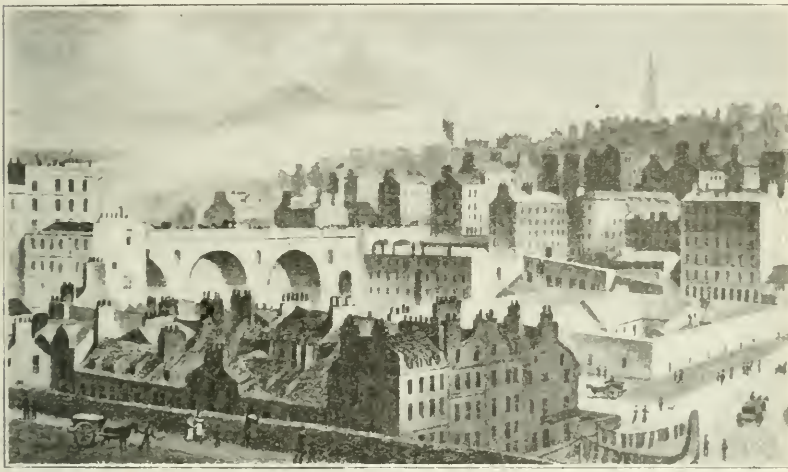
seventeenth century, owing to the high price of building ground and the habit which the inhabitants of Edinburgh had acquired of living above each other in separate floors of the same house, it had been necessary to raise the buildings to a very dangerous height; it was, therefore, enacted by the Scottish Parliament in 1698 that no new house facing on a public street should exceed five stories, but as this law applied only to the front of a building, it not infrequently happened that from the inequality of ground, the back part consists of eight, ten or even more stories." The Act to which Shepherd refers is entitled "Act Regulating the Manner of Building within the Town of Edinburgh." An extract will be given:

" . . . . That the first story be three foot thick, the second story two foot nyne inches thick, the third story two foot six

*Engineering Department, American Bridge Company, New York City.

inches thick, the fourth story two foot three inches thick and the fifth story two foot thick. . . . And Statutes and Ordaines that all new houses be built no higher than fyve stories above the calsay as also that each puncheon load of lyme be refreshed at least with one or two loads of sea sand besides the old rubbish of lyme that may be made use of. . . . " ("The Acts of the Parliaments of Scotland, Vol. X, 1696-1701.")

Doctor Guthrie, who had these high tenements for his parish from 1837 to 1843, describes the abject poverty, the ignorance and the crime that he found. The sanitary conditions were appalling. How could they be otherwise when a mother had to descend several flights of stairs and mount them again for every pail of water,



Part of the Old Town, Edinburgh. View from Prince's Street. From an engraving made in 1829 for Shepherd's "Modern Athens."

often with a child at her breast and another at her apron strings? The daily accumulation of filth was thrown out of the window on the street below at night.

Robert Louis Stevenson graphically depicts the fall of one of these buildings. It had grown rotten to the core and the entry beneath had closed in, when on a Sunday morning the whole structure ran together and tumbled story upon story to the ground, bringing death and desolation to the dwellers therein.

It is a long way—structurally, chronologically, geographically—from these Edinburgh skyscrapers to those of New York, Chicago and other cities of the United States. Chicago was the birthplace of the modern skeleton construction building. In 1883 W. L. B. Jenney of that city prepared plans for a ten-story office building for the Home Insurance Company, and Freitag says that to this

architect belongs the credit for the conception of skeleton construction. The Tacoma building, 14 stories high (Holabird & Roche, architects) carried the idea nearer to completion. In 1890 the Masonic Temple, a twenty-story building, was erected.

The first skeleton construction building in New York City was the Tower Building at 50 Broadway, erected in 1888-9 and demolished in 1914. The structure was 21½ ft. front, 39½ ft. rear, 160 feet deep and 10 stories, basement and cellar in height. It is said that the architect, Bradford L. Gilbert, established his office on the upper floor in order to allay any apprehension that might be felt regarding the safety of the building. The Manhattan Life Building was a more notable building, constructed later in accordance with the new methods.

These high office buildings commended themselves at once. Offices in them were less noisy, more healthy and better lighted than those in the older structures around them. Business prestige as well as better service was obtained. Floors could be divided to suit tenants. But as buildings increased in numbers and in height, it was found that they were not unmixed blessings, for they encroached upon the rights of the public and often worked injury to their neighbors. The question of limiting their height by law soon came up. Along 1900 it was thought that the limit of height had been reached and that the rate of production would decrease rather than increase. An article, "Limitations to the Production of Skyscrapers," in the "Atlantic Monthly," October, 1902, concludes with, "the mania for mere bigness is subsiding and is bound to give place to a better conception of corporate eminence." Writers were mistaken; both the height and rate of production increased instead of decreased. The title page of the "Scientific American," July 25, 1908, is taken up with an illustration of a 150-story structure 2,000 feet high," which it would be possible to erect upon an area 200 feet square without exceeding the Building Code limit of 15 tons to the square foot foundation pressure."

New York City may be justly called the home of the skyscraper. Nowhere else has it so flourished. Of the 3,500 fireproof buildings in the Borough of Manhattan 1,300 are 10 stories or over in height. Up to January 1, 1917, permits had been filed for 199 buildings of 14 to 19 stories, for 64 of 20 to 29 stories, for 7 of 30 to 39 stories and for 5 of 40 stories and over.

BUILDING HEIGHTS

The term "height of a building," according to the New York code means the vertical distance measured in a straight line from the curb level to the highest point of the roof beams in the case of flat roofs and to the average height of the gable in case of roofs having a pitch of more than twenty degrees. According to the Chicago code for non-fireproof buildings it is measured from the average established sidewalk level to the highest point of the roof

thereof and for fireproof buildings it is measured from the average grade of the street frontage of the building to the top of the highest point of the external bearing walls. Other definitions differing slightly from those of New York and Chicago may be found. Cornices, parapet walls, pent houses and bulkheads are not often considered in determining height, but building codes generally place limitations upon their height and area.

Frame buildings outside of fire limits are variously limited to 2, $2\frac{1}{2}$ and 3 stories, or 35, 40, 45 and 50 feet in height.

Buildings having bearing walls of hollow terra cotta or concrete building blocks are limited to 3 stories and 40 feet in height.

The code of Terre Haute has a clause, "No school building hereafter erected shall be more than two stories and basement in height." The code of Dayton fixes a maximum distance to the upper floor level for different kinds of buildings, the distance for primary, grammar and high school buildings being 38 feet above the average grade.

A long list of cities fixes the maximum height for non-fireproof buildings at 65 or 70 feet, Kansas City (Kansas) allows but 50 feet, Detroit for a certain type allows 100 feet. In Rochester the height of a tenement house "shall not exceed by one-quarter the width of the street on which it stands."

The storm center of the whole subject of building heights is the fireproof commercial building. The factors that enter into its regulation are many and complex. Much has been written on the subject. The "Report of the Heights of Buildings Commission of New York City," 1913, is a book of 295 pages with maps, diagrams and illustrations. The literature on city planning that is becoming so abundant is at one in charging the skyscraper with being a detriment to the ideal city. The old idea that within his lot lines a man owned as far down as he could dig and as far up as he could build is being outgrown. His neighbors and the community now have an interest in the use to which he puts his property.

The arraignment against the high building, briefly stated, is that it shuts out sunlight from the street and opposite buildings, it puts the city to heavy expense in providing fire protection, water supply and sewerage, it is the cause of congestion on the street, adding seriously to the traffic problem. There are also economic considerations raised by the disturbance of land values. This particular phase of the subject is ably presented in an article, "City Taxation and Skyscraper Control," by George L. Hoxie, in the "Journal of Political Economy," February, 1915.

FACTORS INFLUENCING CONTROL

The matter of sunlight enters prominently into any proposed regulation limiting the height of buildings. How much sunlight shall be shut from the building across the street? The altitude of the sun at noon is equal to $90° - (\text{Latitude} + \text{Declination})$. From

this equation it is easily found that on the 22d of December a building 100 ft. high in New York City on the south side of a street running east and west shuts off the direct rays of the sun for a distance of 202 ft. from the base.

Two interesting charts are given in the report of a Committee of the Minneapolis Civic and Commerce Association on Limitation of the Heights of Buildings. The first shows that if the south side of an 80 ft. street running east and west should be built up solidly with buildings 140 ft. high, similar buildings on the north side will receive no direct sunlight below the 10th floor for a period of several weeks in December of each year, no direct sunlight below the 7th floor until after March 21st of each spring and no direct sunlight on the first floor except for a few weeks in June of each year. The second chart shows that the 12th floors of buildings 140 ft. high on an 80 ft. street running north and south have the greatest amount of sunlight, namely, 5 hours at the equinoxes, while the lower floors have the least amount, 1½ hours at the same date.

The natural angle of light is 45°. With this assumption a height no greater than the width of the adjoining street will not shut off light from the opposite neighbor. The code of New Rochelle, N. Y., has the provision, "No building shall project above a line of 45 degrees from horizontal, taken from the building line opposite on the widest street on which it fronts." However, with natural light and sunlight a certain amount of reflected light is obtained. Assuming this at 15° we have a 60° light angle, which the Minneapolis report referred to above states should be the maximum angle used in establishing heights. This allows the height of a building to be 1¾ times (1.73 to be exact) the width of the street.

It is evident that if light alone were considered in limiting building heights, tower buildings would be shut out. "One of the glories of New York is its towers." A scheme proposed by the architect, Ernest Flagg, limits three-quarters of every plot of land to a building height not to exceed 1½ times the width of the street on which it faces with a maximum height of 100 ft. No limit is to be placed on the remaining portion of the plot. An owner is allowed to dispose of his right to build high in favor of any adjoining plot.

It has been suggested that volume be limited rather than height. A regulation worked out for the City of Houston is, "A building may occupy the entire lot to a height not exceeding the width of the principal street upon which it faces, and not exceeding in any case 100 ft. Above this height the cubage of the building shall not exceed one-fourth of such height multiplied by the area of the lot." ("The Regulation of the Height of Fireproof Commercial Buildings," by Arthur C. Comey in "Proceedings of the Fourth National Conference of City Planning.") This regulation does not seem to have been adopted; at least, it is not a part of the present building code of Houston.

Nothing will be said in this article about architectural or

æsthetic effect for the reason that this is seldom considered by the makers of American municipal codes. The time is coming when it will be, but that time is not in the immediate present. "The poverty of imagination and inspiration with which some of our architects have responded to the Gift of Time in the skyscraper is pitiable." In England and on the Continent the skyscraper is unknown. The maximum heights allowed in 29 European cities range from 43 ft. in Zurich to 82 ft. in Vienna. (Table in Report of the Heights of Building Commission of New York City.)

PRESENT LIMITING HEIGHTS

A common limitation of heights of fireproof buildings is 2½ times the width of the street with an absolute limit. Boston has a Commission on the Heights of Buildings. The first Commission was appointed in 1904 and by an Act passed that year the city was divided into two districts. No building in district "A" can be carried to a height of more than 125 ft. above the grade of the street, in district "B" the height is limited to 80 ft. The height of no building in the city may exceed 2½ times the width of the street. The Ames building, 189 ft. high, and two or three others over 125 ft., were built before the Act of 1904 was in force. The litigation that arose from the Boston restriction forms an interesting chapter in legal history.

Other cities in which an absolute limit of 125 ft. is in force are Augusta (Ga.), Cambridge, Charleston, Kansas City (Kan.), Houston, Manchester, Portland (Me.), Seattle, Shreveport, Springfield (Mass.), Waltham and Worcester. Kansas City and Houston reduce the limit of 125 ft. to 100 ft. if the building is used for stores, factories or as a warehouse. In Altoona no building can be more than 125 ft. high "except by special permission." Columbia, S. C., has a limit of 2½ times the width of the street with a maximum of 125 ft., "except it be used exclusively for an office building."

In Brookline the limit is 2 times the width of the street with a maximum of 80 ft. Fitchburg has an absolute limit of 100 ft. and Providence 120 ft. In Washington the height can not exceed 130 ft., "except on the north side of Pennsylvania avenue between First and Fifteenth streets, northwest, where an extreme height of 160 ft. will be allowed." Los Angeles, Pasadena, St. Louis, San Diego, Oakland an South Bend permit a height of 150 ft., though in the latter two the height may not exceed 1½ times the width of the street.

The code of Portland, Oregon, has a classification of building heights based upon the occupancy of building and the ratio of height to least dimension at base. For skeleton frames the maximum height is 160 ft. and five times the least horizontal dimension at the base may not be exceeded. In Spokane the maximum height is 152 ft.; in Grand Rapids and Minneapolis 170 ft.; in Baltimore 175 ft.; in Dayton, 180 ft.; in Chicago, Cleveland, Erie, Indianapolis,

Newark and Paterson, 200 ft.; in Milwaukee, 225 ft.; in New York and St. Paul, 250 ft.

Buffalo limits the height to four times the least horizontal dimension of the building and Denver to four times its least dimension, but not to be more than 12 stories. In Lincoln the limiting height is four times the smallest horizontal dimension at the first floor level. In Seattle "the height of fireproof buildings, except as otherwise provided, shall be regulated by a successive reduction of the areas of the floors above the third floor."

The "Building Zone Resolution" of New York City, adopted July 25, 1916, provides "For the purpose of regulating and limiting the height and bulk of buildings hereafter erected, the City of New York is hereby divided into five classes of districts: (a) one times district, (b) one and one-quarter times districts, (c) one and one-half times districts, (d) two times district, (e) two and one-half times districts; as shown on the height district map which accompanies this resolution and is hereby declared to be part hereof." As may be inferred, the width of the street is the base for determining height, although from two to five feet may be added to the height of the building for every foot it is set back from the street line. On streets more than 100 ft. in width the same height regulations are in force as on streets 100 ft. wide. This makes the absolute limit 250 ft. as previously mentioned.

Cincinnati, Detroit, Louisville, Philadelphia and San Francisco are among the large cities in which there is no restriction upon the heights of fireproof buildings. The code of Detroit expressly states, "Fireproof construction buildings shall not be limited in height." The codes of San Francisco and Salt Lake City have a paragraph, "Class 'A' buildings with all wall loads above the third floor carried on the steel frame shall not be limited as to height."

THE SKYSCRAPER OF THE FUTURE

In 1910 only a dozen cities restricted the height of fireproof buildings. The number has now increased to 50. Other cities will doubtless be added to the list in a few years. A dominant factor in bringing this about will probably be the desire to stabilize property values. In a large city without restriction and already having skyscrapers, "the system of control to be adopted must, unless it be cruelly unjust, apply equally to the existing skyscraper and to new skyscraper construction. . . . The problem of equalizing the lot of real estate owners who have, and who have not, already put up skyscrapers is one of the most serious character." Had New York and other large cities taken hold of the subject 25 years ago, the situation would be far different from what it is at present. The obvious lesson for the smaller city is to ordain from the start the control that will probably be needed in its future growth. The State Building Code of Wisconsin will be quoted: "This code sets no limit to the height of a fireproof building, as it is felt that this

is a matter of general community welfare rather than the safety of the individual occupants. The Industrial Commission strongly recommends that each municipality adopt such a limit, before the rise in central land values makes such action a hardship to the property owner."

The altruistic suggestion has been advanced that no single freeholder should be permitted to build to a greater height than would be permissible for all others to build in a similar way. If this were done the height limit would be low, much less than the 125 ft. limit of Boston. Imagine long streets banked solidly on each side with 10-story buildings! If extended over wide areas the city would be uninhabitable. That such a condition should come to pass is too improbable to be anticipated.

However, ideal regulations for skyscrapers include limits for area as well as limits for height. A building that fully covers a lot is entirely dependent upon the adjacent streets and lots for light and air. If several adjoining lots are thus built upon there can but be an insufficiency of these essentials to convenience and health.

The City of St. Louis has recently passed an ordinance regulating the height, area and use of all new buildings. The city is divided into three types of districts: five heights districts (known respectively as the 45 ft., 60 ft., 80 ft., 120 ft. and 150 ft. heights district), four area districts and five use districts. The practical working of this latest word in city zoning will be watched with interest.

IN MEMORIAM

EDWARD McKIM HAGAR, M. W. S. E.

June 21, 1873 to January 18, 1918

Edward McKim Hagar was born at Salem, Mass., on June 21, 1873. In 1893, at the age of twenty, he graduated from Massachusetts Institute of Technology, and a year later, 1894, completed a post-graduate course at Cornell University.

Mr. Hagar began his business career with the organization of the firm of Edward M. Hagar & Co., at Chicago, a machinery sales concern representing the Mesta Machine Company, Southwark Foundry & Machine Company, and others. In 1901 he was made manager of the Cement Department of the Illinois Steel Company at Chicago. On October 1, 1906, the Universal Portland Cement Company, a subsidiary of the United States Steel Corporation, was formed and Mr. Hagar was elected its president. During his connection with the cement industry he served for two years as president of the Association of American Portland Cement Manufacturers, now the Portland Cement Association. In 1907 he was elected president of the Cement Products Exhibition Company, which held its First Annual Cement Show that year.

On January 28, 1915, he resigned the presidency of the Universal Portland Cement Company to organize a new cement company for the purpose of acquiring and operating a chain of strategically located cement plants across the continent. In reviewing his endeavor to finance this venture, the following side light is interesting. A preliminary agreement had been reached with certain New York bankers and a plan of financing approved. Mr. Hagar and his attorney were just entering the elevator of the building in which the bankers were located, with papers all drawn up and approved, ready for final signatures, when the announcement of the Lusitania sinking was made. The bankers said, "We had better wait until we see what this means."

Shortly afterwards Mr. Hagar was called to New York by another group of financiers and offered the presidency of the Wright Company, which had just acquired control of the Simplex Automobile Company for the purpose of building the "Hispano-Suiza" æronautic motor, now well-known at the front abroad. Later, the Wright Company took over the Glenn L. Martin Company of Los Angeles, æroplane manufacturers, and the Wright-Martin Aircraft Corporation was organized with Mr. Hagar as its president. Here his great enthusiasm and belief in the ultimate future of the aircraft industry could not be confined within the limits set by his Board of Directors and on February 17, 1917, he resigned the presidency of that corporation.

He next became connected with the American International Corporation, where he organized and on September 7, 1917, was

elected president of the American International Steel Corporation, a subsidiary formed for the purpose of merchandising American steel and steel products abroad.

Mr. Hagar's was a forceful character, ever active and always driving ahead. One meeting him for the first time was immediately impressed with his peculiar and intense magnetism.

He died at his residence, 950 Park avenue, New York, on January 18, 1918, of acute pneumonia after an illness of five days. Many will mourn his departure and revere his memory.

He was a member of the following clubs and societies:

American Iron & Steel Institute,
American Society of Mechanical Engineers,
American Society for Testing Materials,
American Society of Civil Engineers,
American Institute of Mining Engineers,
Automobile Club of America,
Technology Club of New York,
New York Yacht Club,
The Riding Club, New York,
Engineers' Club, New York,
University Club, New York,
The Recess Club, New York,
Duquesne Club, Pittsburgh,
Chicago Club,
Phi Kappa Psi Fraternity,
Western Society of Engineers (since July 30, 1898).

(Signed) B. F. Affleck,
J. H. Libberton.

ROBERT KUNSTMAN, M. W. S. E.

Robert Kunstman was a native of Germany and received his education as a mechanical and civil engineer at the technical schools of Munich and Carlsruhe. To the academic training was added an unusual amount of study of geology, mineralogy and kindred subjects which were of great value to him in this later work.

Mr. Kunstman's first duties after leaving school were in connection with iron bridges, then just coming into general use, in 1855 to 1858. Shortly after this he moved to England, spending several years there with firms engaged in the manufacture of locomotives, railway equipment and spinning machines. During this time he became a British subject, which citizenship he retained through the remainder of his life.

For several years, from 1863 to 1867, Mr. Kunstman was engaged in the introduction of agricultural machinery into Germany and the neighboring countries, but in 1868 he foresaw the wonderful development of New Zealand and Australia, and spent the best part of his life in those countries. His work was largely engineer-

ing and construction, and particularly factory and plant construction. For some years he was head of the government building projects of Sydney.

In 1893 Mr. Kunstman came to the United States, establishing himself as a consulting engineer in Chicago. While engaged in railroad work at this time he learned of extensive deposits of soapstone in the State of Arkansas, not far from Little Rock, and for some years endeavored to develop them. In this he was only partially successful, although it is highly probable that his commendable tenacity of purpose would have ultimately put the enterprise on a satisfactory basis.

Public affairs were of great interest to Mr. Kunstman, particularly matters relating to construction and engineering. Among his hobbies, if such they may be called, was the betterment of the sanitary conditions in public and semi-public buildings. He was also greatly interested in the use of permanent building materials, and held patents for a number of processes and formulas for building materials, paving materials, concrete block, fire brick and other refractory products. Being familiar with the effects of natural and mechanical destructive agencies on these materials, he endeavored to provide substances resistive to their destruction and disintegration.

While engaged in his various activities, Mr. Kunstman found time to contribute many technical articles of an educational character to the scientific magazines, and among his business and private associates was known as a public-spirited man of great information. As a Mason he served through many offices and received the highest honors of the Order while in Sydney.

Mr. Kunstman became an active member of the Western Society of Engineers in 1893, and took great interest in the proceedings of the Society, and it was his regret that his duties prevented his being more closely associated with its activities.

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings.

MEETING NO. 1009, JUNE 3, 1918.

This was a general meeting of the Society, Mr. W. W. DeBerard, Trustee, presiding. In connection with the Fuel Week designated by Federal authorities, a program to consider the fuel supply had been arranged. The Chairman introduced Prof. H. H. Stoek, Chairman of the Coal Conservation Committee for the United States Fuel Administration for Illinois, who briefly outlined the work of the Fuel Administration. Prof. Stoek introduced Mr. David Moffett Mayer of the Bureau of Mines, Consulting Engineer for the United States Fuel Administration. Mr. Meyer described the engineering features of the Fuel Administration and the proposed examinations and reports on various boiler plants throughout the country.

Dr. F. C. Honnold, District Representative of the United States Fuel Administration, described the operation of his office in distributing coal and also the limitation upon the supply for this market.

Mr. C. E. Naylor, Consulting Engineer, Chicago, pointed out the economy which is at present being obtained in the conservation of coal in the Chicago loop district.

Mr. W. D. Langtry described in detail the fluctuation in the ash content and B. t. u. in coal during the last two years, showing very clearly that the ash content had increased while the thermal units decreased.

Mr. Osborn Monnet, formerly Smoke Commissioner of Chicago, described the difficulties in eliminating smoke from Chicago territory. Further discussion was had by Mr. Wilson, editor of Power; Mr. Rankin, associate editor of Electrical Review, and Mr. Holbrook, who described the work of the Iowa State University in examining the power plants in Iowa.

There were present fifty members and guests.

MEETING NO. 1010, JUNE 10, 1918.

This was a meeting of the Bridge and Structural Engineering Section, with Mr. G. A. Haggander, Chairman, presiding.

Mr. L. K. Skov, Assoc. W. S. E., Assistant Engineer, Bridge Department, C., B. & Q. Ry., presented a paper on "Concrete Caissons Sunk by Open Dredging Method." The speaker described the method adopted by his company, applying well known practice to concrete bridge piers and abutments, which has resulted in considerable economy and which expedited the work. The designs mentioned in the paper were executed under the direction of the late C. H. Cartlidge, while he was Bridge Engineer of the C., B. & Q. Ry. Co. The paper having been sent out in advance was presented by abstract and was illustrated with numerous slides showing in detail many examples of this type of construction. Additional data was presented in the discussion, which was participated in by Messrs. Parsons, Hadwen, Marquardsen, Lacher, Grant, Dalstrom and Lord.

The meeting was attended by sixty-seven members and guests.

MEETING NO. 1011, JUNE 17, 1918.

This was a joint meeting of the Electrical and Mechanical Engineering Sections W. S. E., the Chicago Section, A. S. M. E., and the Chicago Section, A. I. E. E. The meeting was attended by 130 members and guests.

A one-reel film illustrating turbine manufacture, furnished by the General Electric Company, was shown and proved to be very interesting.

Mr. C. A. Keller described the organization of the War Committee of the Technical Societies of Chicago, and illustrated his address by lantern slides and a diagram showing the organization and the possibility to complete affiliation of the Technical Societies of Chicago.

Mr. J. L. Hecht, Chairman of the Mechanical Engineering Section, presided and introduced the speakers. Mr. Eskil Berg, General Electric Company, Schenectady, N. Y., presented a paper on "Advantages of High Pressure and Superheat as Affecting Steam Plant Efficiency." This paper created considerable interest as a method of conservation of coal and increased efficiency. The address was illustrated by numerous slides.

Mr. D. W. R. Morgan, Engineer, Condenser Department, Westinghouse Electric Manufacturing Co., East Pittsburgh, Pa., presented an illustrated paper on "Condensers."

The following participated in the discussion: Messrs. Almert, Kerr, Bailey, Kerner, Osterman, Budd, Heald, Wheeler, Nechin, Riggs and Gebhardt.

MEETING NO. 1012, JUNE 27, 1918.

This was a joint meeting of the Western Society of Engineers, Chicago Section, A. S. M. E., Chicago Section, A. I. E. E., and the Society for the Promotion of Engineering Education. The meeting was held at Engineering Hall, Northwestern University, Evanston, Illinois. The total attendance was seventy-five. Mr. A. S. Baldwin, Third Vice-President, presided.

Mr. W. L. Abbott, Chief Operating Engineer, Commonwealth Edison Company, spoke on the subject of the experience of his company in supplementing college training and in developing young technical men in responsible positions with his company.

Dr. C. R. Mann of the Committee on Education and Special Training of the War Department, presented a résumé of the policy recently adopted by the War Department with reference to students in technical colleges.

Mr. F. J. Gernandt, Superintendent of the Plano plant of the International Harvester Corporation, presented the problems which had arisen through introducing women employees into their plant.

Mr. Henry G. Cox of the International Harvester Corporation, presented comparative data as to the effectiveness of women in shop work as compared with the former employment of male labor.

Mr. John R. Bibbins, Resident Associate, Bion J. Arnold, presented a résumé of the importance of industrial research in colleges.

Mr. A. S. Baldwin presented a résumé of his observations on the adaptation of technical graduates to railroad engineering and urged the importance of conserving the engineering talent of the country for special service in technical lines as a matter of domestic economy.

BOOK REVIEWS

Use of Water in Irrigation. By Samuel Fortier. 318 pages, 6 by 8 inches, with illustrations. Bound in cloth. Published by McGraw-Hill Book Co., New York. Price, $2.00.

This is the second edition of this well-known book. It has been revised and enlarged. The principal additions are in the articles on Irrigation in Foreign Lands and Sewage Irrigation. The first edition contained a good description of American practice and the addition of foreign practice forms a valuable supplement to this work. The uses of irrigation in eighteen foreign lands are described.

The volume is one of the Agricultural Engineering Series. It is evident that the author has made use of the access to governmental statistics. The greater part of these are of the date 1910. Realizing the great progress that has been made since that time, the reader is led to wonder what the comparisons would show if brought down to date.

As an engineer, the author discusses the flow and measurement of water through weirs and channels. Several tables are given and many of these should be of value in the field of hydraulics aside from their particular application to irrigation problems.

The engineer who reads this work is impressed with the great amount of information set forth for the use of prospective farmers of irrigated lands. Classification of soils and crops and proper planting conditions are discussed in detail. There are many useful hints as to possible pitfalls for the unwary purchasers. Many legal points in the steps necessary for purchase, maintenance and protection of titles to irrigated lands and water rights are covered. In this respect, the book is particularly of value to the engineer who is new in the study of irrigation and to the farmer of irrigated lands.

Nine different methods of applying waters to soil are described. There are many ingenious devices and methods included among these.

While the value of the volume is greatest to the irrigation farmer it is an educational and instructive addition to an engineering library.

The first edition of this book was reviewed in the January 1915 Journal of the Western Society of Engineers., Vol. XX.

H. E. H.

Ports and Terminal Facilities. By Roy S. MacElivee, Ph.D. First Edition, 315 pages, 6 by 9 in. 117 illustrations. Bound in cloth. Published by McGraw-Hill Book Company, Inc., New York. Price, $3.00.

It required a great war to make the people of the United States realize the limitations of our shipping facilities, and a study of this book will give one the underlying reasons for the difficulties of making ocean shipments during the last few years. Although many changes are being made along the water front, the book will never really be out of date, for the principles will remain firmly established.

In many respects, as the book shows, European countries have grasped this situation more fully than we have. This is only natural, as we were an importing country and had such vast stocks of war materials that we could afford to neglect efficiency anywhere along the line. Today, however, we are faced with the necessity for producing much that we formerly imported and for exporting many products for which heretofore we had only a local market. Brought face to face with the after-the-war problem of a world market, and a present problem of greatly increased shipments, many realize that the shipping problem is closely related to Terminal Facilities. The European cities have developed their ports, often with Government assistance, and this work is fully described. The effect on a city having suitable port and terminal facilities is obvious after a study of the book, and it may be used for that purpose by Chambers of Commerce and similar organi-

zations. Each subject is treated in great detail, making the discussion valuable.

Among the subjects discussed are: The Relative Importance and Physical Characteristics of the World's Leading Ports, General Characteristics of a Well-Co-ordinated Seaport, Port Competition for Rail and Maritime Freight, The Harbor Belt Railway and Competition at the Terminals, Lighterage, Cartages, Drays and Motor Trucks, Piers, Wharves and Quays, Wharf Equipment, The Warehouse, Standard Package or Specialized Freight, Bulk Freight, Inland Waterways and the Seaport, The Industrial Harbor and Upland Development, The Free Port as an Institution, The Processes by which the Free Ports of Hamburg and Bremen were created. Included is a complete Bibliography of both Foreign and American books, Pamphlets, Official Reports and Documents, Addresses, etc., bearing on the subject.

C. A. M.

Handbook of Mechanical and Electrical Cost Data. By Halbert P. Gillette and Richard T. Dana. First Edition. 1734 pages, 5 by 7 inches, with many illustrations. Bound in flexible red leather, and published by McGraw-Hill Co., Inc., New York. Price, $6.00.

Sooner or later the question of cost comes up on every project. Often these costs must be determined from relatively little data, by comparative estimates and other means of requiring considerable judgment. The greatest judgment is required when it is not known just how published costs were obtained and what factors were taken into consideration in making up the figures. Costs often vary with the personality of the individuals making them, and while it will never be possible to compel all cost accountants, estimators, etc., to use identical methods, there is no doubt but that there are facilities today by which the progressive engineer can more closely approximate the results desired, than was possible a few years ago. One such means is through a study of the methods used by the authors of this handbook in collecting the vast amount of data presented on the special subjects covered.

Cost data, when properly made up, will be as valuable ten years hence as at the present day. The ability to appreciate changes in unit costs is the one handicap which confronts the engineer. In this handbook much effort is directed toward showing the necessity for detailed information of the conditions under which the costs were made up in the first place.

One of the most valuable chapters is the first, covering General Economic Principles. Here are explained the proper methods to use in making up costs, attention being called to the systematic errors followed by some who appreciate only part of the subject.

Among other chapters, whose titles indicate the general nature of the subjects covered, are: Depreciation, Repairs and Renewals; Buildings; Chimneys; Moving and Installing; Fuel and Coal Handling; Steam Power; Internal Combustion Engines and Gas Producers; Hydro-Electric Plants; First Cost and Operating Expenses of Complete Electric Light and Power Plants; Overhead Electric Transmission and Distribution; Underground Electrical Transmission and Distribution; Lighting and Wiring; Belts, Shafts and Motor Drives; Compressed Air; Gas Plants; Pumps and Pumping; Conveyors, Hoists, Cranes and Elevators; Heating, Cooking Ventilating, Refrigerating and Ice Making; Electric Railways, and one entitled Miscellaneous, requiring some hundred pages to cover what might not be included in any of the other headings.

It is manifest that the subject of cost is a vital one, and it is evident that the authors have appreciated the importance. To cover it well has required many pages and yet each separate item is covered in the fewest possible words compatible with the idea of making the handbook fulfill its mission.

C. A. M.

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WESTERN SOCIETY
OF
ENGINEERS

PAPERS, DISCUSSIONS, ABSTRACTS, PROCEEDINGS

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JOURNAL OF THE
WESTERN SOCIETY *of* ENGINEERS

VOLUME XXIV | JANUARY, 1919 | NUMBER 1

Addresses at the Annual Dinner of the Western Society of Engineers

January 22, 1919.

CHARLES B. BURDICK, *Retiring President.*

THIS society has every reason to celebrate tonight. In the autumn, when we first laid plans for this meeting, we were still in the shadow of war, but the black cloud has been lifted and we can rejoice in the sunshine of a great national victory for right, and as soldiers and civilians we can rejoice in the consciousness of having done our parts within our abilities and opportunities. As a society, we have completed fifty years of good work and our prospects for continued usefulness were never brighter than now.

Fifty years is not long on the background of the past. But in the useful arts it measures a progress greater than all the ages before. This society has seen steam transportation grow from a slender thread across the continent to a network connecting every city in the land. It witnessed the very beginning of applied electricity and studied its application step by step, in lighting, telephony, power, and local transportation. It saw the horse retired to a well earned rest through the application of the gas engine to road vehicles. More recently man has learned to fly. The wireless spans the ocean. The phonograph permits us to hear the greatest singers in our homes, and the moving picture brings distant lands before our eyes.

All this has been accomplished within the life of this society, and it has recorded each step, and through its papers and discussions it has helped to make each advance a permanent gain—a stepping stone in progress.

Our constitution defines the objects of the society as the "Advancement of the science of engineering and the best interests of the profession," among the means employed being meetings for the reading of papers, and for professional and social intercourse. The greater part of the society's work has followed the wording of the constitution quite closely.

In these material days there have been those inclined to belittle the value of technical discussions, and to bear heavily on the "wel-

fare of the profession," reading into it in large letters the chase for the almighty dollar.

Practically all of us practice engineering as a means of livelihood, in which the dollar goes far to measure our accomplishments. Therefore, none of us may *scorn* it, and there is no doubt that the welfare of the profession has an important relation to it. But as a profession we want to *earn* it, and earned, we want to keep it, or know where we can get more, leaving the field open for those who follow us.

There is probably no line of human endeavor where chance plays a smaller part in success than in the pursuit of the sciences. To aptitude there must be added education, which permits the engineer to begin each task where his predecessor dropped it. Life is too short and the pace is too fast for the man who would ignore accumulated knowledge. The pickings are lean in thrashing over old straw.

In the useful arts at our hand today, there is *not one* solely dependent on the work of an individual. We commonly accredit the steam engine to James Watt, yet he was preceded by Hero, the Greek, who furnished the original inspiration, Somerset, who described a steam pumping engine, Papin, who invented the safety valve and the piston, and Savery, who built the first practicable engine. Newcomen added the condenser. Watt deduced the fundamental principles of engine design and put them into successful practice. Andrew Carnegie says of him, "The best proof that he was a man of genius is that he first made himself master of all knowledge bearing upon his tasks." He was followed by Stephenson, Fulton, and many others, each picking up his work where he found it and passing it along to the modern engine.

Education begins with life and ends with death. Technical education begins in the schools, and if it ends there, then the engineer is dead, for engineering never stands still. The library is useful for reference to the past, but contemporaneous progress is only gleaned from contact with the engineer and his works, and it is in the technical societies that this contact is best obtained at first hand.

Thus, the benefit of society work is not confined to a record for posterity, nor even the exchange of information among present members, great as is this service. The return to the member who participates is prompt and positive. He educates himself in presenting his message to others. It is no doubt true generally that none receives a greater benefit from an engineering paper than the man who prepares it. Those who miss the opportunity thus to benefit from the society lose one of its chief advantages.

But we are not all benefitted to an equal degree, nor is the gain equal from year to year. Some will reach a time when perhaps their duties are of such executive nature that they get out of touch with pure engineering, and some of such may feel that society work is too great a burden, and the *unthinking* one may

reach the point where he questions its value, because he personally does not feel the need of it. If so, then it is well to remember that the society represents all grades of membership, that there are others less fortunate who need to keep abreast of the engineering times, and who need the acquaintance that comes from contact in the work of the society. From the standpoint of earning capacity, the engineer has no better asset than to be well and favorably known among engineers. This is true, regardless of the engineer's position, whether in purely scientific or commercial endeavor, whether depending on fees for a livelihood or working upon a small salary.

Thus, if the engineer would succeed from any standpoint, he must, first of all, prepare himself,—he must "make good." There is no other road to a permanent success.

But we must not neglect the entirely material aspects of the engineer's livelihood. I believe the society is justified in proper efforts looking toward better compensation for engineers. But anything savoring of trade unionism would be the most positive detriment. The engineer's best stock in trade is his absolute loyalty to the job. It opens fields of unlimited possibilities that would be closed, and properly so, by any evidence of a tendency to coerce, or to standardize service.

But there are many things we *can* do that would be in the interest of the individual engineer and the public; no doubt more than we have done in the past. We can use our influence to see that technical men are appointed to public positions requiring technical skill, and that remuneration is provided sufficient to attract men of capability. We can help to educate the public to better appreciation of engineering and the necessity for adequate compensation. We can increase our facilities for solving the question of unemployment, particularly among our members. Especially, we should see to it that every engineer returning from the war should find something to do. This would be a proper activity for our war committee which, through its affiliations with other Chicago technical societies and its funds already available, could accomplish much.

The radius of individual accomplishment is helpful though small. The local or sectional society with occasional meetings only imperfectly represents engineering in a limited territory. The technical profession as a whole needs one voice and one mind in dealing with matters of national importance. The technical man is fully awake to this necessity today, and all the societies are bent on new activities looking toward co-operation. The four founder societies recently have formed The Engineering Council, in which local societies of standing are invited to membership, having the purpose of representation for the technical profession in all matters pertaining to its general welfare, through certain representatives, suitably remunerated, who can devote as much time as necessary to

the work. The Western Society has been invited to membership, and I look for great good from this association.

The past war year has been a hard one for the Western Society. Our income has been reduced through the remission of dues to soldiers, and our expenses have been increased. Seventeen percent of our membership were in the army and half the officers were absent upon Government work nearly all the year. It has been hard to secure a corporal's guard at a committee meeting. And yet some splendid work has been done. Through the able work of Mr. Copeland, the war committee has done a patriotic service in connection with the drives for Liberty bonds and the war charities. A war year would naturally be a poor one for increase in membership, and yet it has seen a greater addition to our roll than any year in the past decade, largely through the work of Mr. Kinney's increased membership committee.

The sectionalizing of the society has been a good thing. This year a gas section has been organized, and we are enrolling the engineers and managers of middle west plants that have not been heretofore interested in the work of the society. Steps are under way to amalgamate the Structural Engineers' Association of Illinois and take over the protection of the State Engineers' License law.

In this great manufacturing center we should have an industrial section. It is not too much to expect that it could be instrumental in doubling our membership if handled in the right way. Our past president, Mr. Onward Bates, has suggested a plan through which industrial memberships to individuals, firms, and corporations would greatly add to our resources, thus permitting increased usefulness. I hope something of the kind can be brought about during the coming year.

In completing my term as president, let me again thank you for the implied honor. Also, I wish to express my thanks for the ready response that has been received from officers and members, and especially the secretary, in conducting the society affairs. In stepping into the ranks I pledge my aid in the future affairs of the society in what I believe to be a growth and usefulness greater than ever before.

Mr. A. S. Baldwin, *President-elect.*

Gentlemen, you have some interesting events coming, and I will take but a very few minutes of your time. I think I need not endeavor to express to you my appreciation of the honor that you have conferred upon me. It is an honor that, to my mind, at this time particularly, carries a serious responsibility, from you to me, as well as from me to you. A spirit of unrest pervades the whole world. It is not restricted to the laboring classes, but it permeates society, and is reflected in every branch of society, and society will, I believe, be still more seriously affected in the days that are to come. It is reflected among engineers even now in the steps

that are being taken by the four great national societies that we have become accustomed to call "The Founder Societies," and the steps they are taking through their committees on development and other measures to keep themselves not only abreast of the times, but in advance of the procession.

There is a tide in the affairs of men, that, taken at its flood, leads on to fame. It seems to me that the affairs of engineers are at their flood tide today. Never before in the history of the world has their ability and their accomplishment been so widely recognized. The great war was well called "The Engineer's War," and the engineers who designed and advanced the great engines of destruction must now turn their attention to the engines of reconstruction and try to see that their endeavor shall be for the benefit of humanity. We who have been at home and unable to participate directly in the great events that were going on abroad, have now our chance to bring into a hearty and a whole-souled coöperation all of those who have been abroad, and derive from them the benefit of their experience and of their loyalty, help and faithfulness. It is for us to seize this occasion, every one of us, to try to further the interests of our society. Remember that charity begins at home, and that right here in our midst is the opportunity for us to help our profession. When we consider the large number of engineers who are in this immediate vicinity and who are eligible for membership in this society, and reflect upon what would be the power and the influence of this society if every one of them were engaged with us in a hearty and enthusiastic effort to advance the interests of our profession, not selfishly, but for the benefit of the profession, and the benefit of the world at large, we can realize what our opportunity is, and so I ask you to join with me this year, hand in hand, and shoulder to shoulder, to go forward with a determination that it shall see a march forward and a progress such as we have not seen before. In that way we may gain the influence and prestige that is rightly ours. I look to you for that coöperation, and I look with confidence, because I feel sure that you can be depended upon in the future, as you have been in the past.

Brigadier-General J. J. Morrow,

Chief of Engineers, First Army, American Expeditionary Forces.

I don't know why everybody wants to talk about Daniel in the lions' den, but my particular case demands a preceding explanation. It really is a crime for a technical man, a trained engineer of thirty years' experience, to come before an engineer society as this is, with a paper which has been so illy prepared. General Taylor was the first chief engineer of the American Expeditionary Forces, and he was to have addressed you this evening on the subject of engineering with the American armies in France. Less than forty-eight hours ago the buck was passed to me, by reason of the fact that General Taylor had to appear before a senate committee and could not leave Washington. Of that forty-eight hours I have

spent twenty-four hours on a train, leaving me less than twenty-four hours to throw together roughly a few notes. The notes which he had prepared were not entirely applicable to my use, as his experience was not with the army at the front, and my experience was entirely there. I had to use his notes as to the details of some of the things which had been going on a year before I got to France, and which continued to go on while I had my own worries at the front, and then had to get together a certain amount of data as to my own experience. So, with this apology as to the crudeness that this talk of mine must of necessity take, I throw myself on your mercy. I have some slides, and, with your permission, I will give you a little of the statistical part of the talk first.

When the American army went to France a year and a half ago it consisted of nothing but General Pershing and his staff. General Harry Taylor, then a colonel, went over as chief engineer of the expeditionary forces. The first troops that got over there were nine regiments of engineers, one of which was raised right here in Chicago from the railroads centering in this city. The First Division soon followed and got there along with some of the railroad troops—but the first work was largely one of organization, and there was considerable groping in that organization, as it was necessary to fit the American troops which were coming along into a plan which was constantly changing, and to prepare a place for the troops that were coming. The French and the British were behind the lines in large numbers and had occupied most of the available space. Our army was confronted at once with a perfectly tremendous construction program and about half of the railroad troops that went over there were turned into construction troops. The rest of them were put on railroad work assisting the French and the British armies, who were badly in need of their services.

The organization which did most of our work of construction in France was an organization at one time under the chief engineer of the line of communication, and finally under the chief engineer of the expeditionary forces, the division of construction and forestry, and that organization through the eighteen months of its existence did a tremendous amount of work of all sorts.

It might be well to trace briefly the scheme on which it was organized. It was necessary immediately to prepare the ports to receive supplies and to receive troops, and at the same time to prepare places in the forward areas for the troops to train and to prepare storehouses all over France. An organization was effected by a division of the base into seven sections, the intermediate zone between the base and the forward area into two sections, and an advance section immediately behind the troops, near Toul, where it was at first thought our troops would go in; and then another section known as the section of special projects. To each of these was assigned a section engineer, reporting to the chief engineer of the division of construction and forestry, who had a deputy.

The work was accomplished by forces which grew to between 150,000 and 175,000 men, distributed through the entire area of France.

A forestry regiment followed very shortly, and then a larger forestry regiment about three or four months later, and these, with the sapper engineer regiments which came over with the earlier divisions, besides some civilian help which was picked up, constituted the labor force that did this work.

Type plans were used as far as practicable. The director of construction and forestry, with his central office, controlled the work, his deputy being in charge, and the section engineers were given great latitude and absolute support as long as they adhered to the established policy. The deputy remained at the office and carried on the work in accordance with the definite policy laid down, which left the director considerable freedom to get around and see his section engineers and to get an intimate control of the work. This turned out to be an exceedingly satisfactory type of organization for this great amount of work, scattered over so large an area. The labor forces were always inadequate and always changing. The divisional troops had to leave and others had to be gotten to take their places, and the Division had to give up troops afterwards when the army was formed. The technical troops, however, were mainly used for purposes of supervision and labor troops were sent over.

Now as to the classes of work. They had to build shelter for the troops, including all kinds of camps, and prison camps for prisoners of war, instruction centers, schools, hospitals, ports, docks, warehouses, railroads, storage depots all over France, water supplies, sewers, gasoline and oil stations, motor transport centers, remount depots, refrigerating plants, salvage plants, and, in fact, practically everything in the way of construction that an army can possibly need. Practically all of this work was done by this one division under the chief engineer of the American Expeditionary Forces.

Railroad operation was turned over to the director general of transportation, and he had charge of the construction of the railroads for a period of about five or six months; but in spite of the fact that he had charge of that construction from some such time as September, 1917, to March, 1918, 93 percent of all the railroads that the American Expeditionary Forces built in France were built by the division of construction and forestry. They turned out nearly all of the lumber used in this large construction program. Of shelter, they built 11,862 barracks. The number of barracks which they erected, placed end to end, would reach 225 miles, 20 feet wide. As to hospitals, they biult hospitals for 280,000 beds. That amounted to 7,700 hospital barracks, or 127 miles of wards, and the hospital construction was always kept ahead of the need for its use. At the time the armistice was signed projects were canceled which authorized about 120,000 additional beds, but at that time there were available 280,000 beds, of which 190,000 were occupied, and at just about that rate the construction of the

hospital accommodations for the American Expeditionary Force was kept in advance of the necessity for their use.

The first main ports were at St. Nazaire, Bordeaux and La Pallice, but later Marseilles, Brest and other ports were brought in. Up to November 1, 67 ship berths had been obtained from the French, 12 constructed, and work projected on the construction of 28 more. The number of berths kept in advance of the necessity for their use. For September and October the total number of berths actually used was 63, and the number available 77. During this time there were occasions where one or two vessels were waiting in the ports for berths, but the berth spacing until after the armistice was signed, when the ships came over a little faster than they could be handled, except for the first five or six months, kept ahead of the ships.

They built large storage yards at five different places over France, engine terminals at ten different places. The work necessary to prepare the main railroad systems included the construction of large storage yards at each port with tracks leading from the piers to the yards, appropriate receiving yards, warehouses, tracks, departure yards and large depots at the ports and at the intermediate and advance stations, with regular service, which the stations demanded. Now it was found that the plans which were made were a little too elaborate. When the demand came for a more rapid shipment of troops the plans had to be much cut down. There were too many tracks for the service of the storehouses and for the service of the depots to be gotten down so that the army at the front could be supplied, so the plan was adopted of putting in such tracks as were absolutely indispensable and leaving the trimmings until later. And the trimmings never got in, as the armistice closed operations, but the yards were functioning with the tracks that were necessary. The great demand for troops which occurred last spring and summer caused considerable embarrassment to everybody in the expeditionary forces, and in the English and French forces as well; but in the railroad project, it was decisive, in order to complete the necessities for getting at work some six or eight months sooner than had been planned, and it was humanly impossible to get the construction done in that much less time than the original project allowed.

There were storehouses built to cover nineteen and a half million square feet. That is a figure that is intelligible to an engineer, but it shows the magnitude of the project that these engineers were engaged on behind the army in France. The roofing was usually a rough rubberoid combination, but later corrugated iron roofing was adopted, and some of the storehouses were built without siding.

The remount and veterinary hospital construction was not so elaborate, because the horses never came over in any great numbers. That was one of our great troubles. We were handicapped all the time by lack of horse flesh, particularly those of us at the front.

There was, however, remount construction for 48,000 animals and veterinary hospital construction for 28,000 animals. That does not mean stable accommodation for the horses; that is for depot and hospital handling of the horses.

Water supply and sewage projects were put in all over France, and a system of water analysis laboratories established. The water supply and the water service was placed under about the same kind of care as is done in most of our up-to-date municipal establishments. Refrigerating plants were put in. The plant at Gievres is the largest refrigerating plant in the world.

Bakeries were put in, one at Is-sur-Tille, which was one of our forward regulating stations, with a capacity of 500,000 pounds of bread per day, and which was being enlarged to an ultimate capacity of 700,000 pounds per day. And complete plans were drawn up for another bakery for a capacity of 400,000 pounds of bread per day.

Power plants were established all over France, a number involving as much as five thousand kilowatts. Oil and gasoline storage stations were established, one at La Pallice of four tanks, 25,000 barrels apiece, three other large tanks and several plants were built for smaller storage in the forward areas.

The work of the forestry section of this office was one of the most important. They found they had to turn out practically all the lumber that the A. E. F. needed. We attempted to get some of it from the French and the English, but they had to expand their own forestry work in order to get the lumber at all, and something like eighty or eighty-five per cent of all the lumber we used was turned out from the forests of France by this division. They were turnig out eighty million board feet a month at the close of the war, and at the time of the signing of the armistice there were working in France ten thousand technical lumbermen and saw-mill men, three thousand road and bridge troops, and eight thousand labor troops. The forestry division was supervising the operations of about eight thousand other troops employed on the production of cord wood, and there were twenty thousand more being raised in the United States to go over to meet the increased demands. This work was much complicated by the French regulations. The forests over there are a part of the national wealth and are treated as such. Complicated arrangements had to be made for cutting. You have to cut the tree that the forester locates, and you have to cut it off squarely at the ground. You have to clean up all the brush for use as fuel. None of it is wasted. Of course our troops had a great deal of difficulty because none of them were used to anything of that kind in forestry work. The French knew nothing about our mills. Our saw mills were a source of wonder to them, and the ovens which burned the saw dust had never before been seen in France, apparently.

A large organization was developed for the purchase of supplies in England. A purchasing board was organized in Paris

which purchased about two hundred million dollars worth of supplies in Europe, which did not require ocean transportation from the United States. That was the critical thing in all of our operations, getting tonnage to get the stuff to the troops, and anything we could do to save ocean transportation was a help. There were over a million tons of material purchased in Europe and supplied to the armies without the necessity of any ocean transportation for any of it except, of course, across the channel.

They also had a quarry service organized. This was done by a special quarry regiment raised in the states and sent over there, others following it. They were turning out twenty thousand cubic meters of crushed rock per month, and in addition to that twelve thousand cubic meters were being turned out by troops assigned to the forward areas, or about thirty thousand cubic meters a month being produced.

They established a camouflage factory that grew from a small dance hall in Paris, occupied by one hundred employes, under thirty enlisted men, to a factory at Dijon later which consisted of four commissioned officers, one hundred fifty enlisted men, and nine hundred civilians. They turned out fifty thousand square yards of camouflage cover for artillery per day, and, in addition to that, considerable cover for engineer and hangar camouflage, a total of about three million square yards a month.

We had to take over a map organization to make our own maps and to do the field work to get the data necessary for them. That was done largely,—practically entirely,—by the civilian branches of our government service. They organized it, equipped it, and it took over and it grew from a small installation in Paris, and from a small detachment from the 29th Engineers, to the largest map printing plant in the world, covering one hundred thousand square feet of floor space. It was turning out in printed matter from about one hundred prints a day, at which it started, to the record run in November of 130,000 lithographic prints and 35,000 type-sheets in 24 hours. During the month of November two million lithographic prints and over one million sheets of printed matter were turned out. They were furnishing all of the plans used by the forward armies, and, in addition to that, were doing photographic work and model work. In addition to that central printing plant at the base they had outfitted and equipped a battalion for each army that was formed and had a plant in the forward area operating with that army, which was doing all of the printing of maps for the army except the base maps, which were obtained from the rear, and an overprint was put on it to show the positions and the additional data necessary.

We never got any United States pontoon equipment over there because there was no room on any ships to take it over. We got one pontoon park. The French furnished a few boats, but we never had the necessary horses, but this equipment did get into action on the Moselle in the last days of the war.

A search-light corps was organized that got across and did excellent work with the army. They established a school at Gondrecourt, trained the men and got in during the last three months of action.

A chemical warfare service was organized by the engineers, but afterwards removed from its control, becoming a separate arm of its own, but the chief of the service and its four senior officers were officers formerly of the corps of engineers and they did some wonderful work. In addition to this there were other services organized, on which I will not dwell, the engineer school at Langres and the big department of engineer supplies. That was handled through our depots by the director of military engineering supplies, and they furnished equipment not only for the engineers, but the engineer equipment for the entire army, and also the tremendous quantities of engineer stores which were needed, at least until the time when we adopted the German habit of taking the stores in through the front lines, about the first of July.

With this rough sketch of the preparatory work, and with what might be called the supply work, I will come down to the work of the engineers with the troops, and to do that, in order to make it a little clearer, I think I had better give you a rough sketch of about how the engineers are organized in our combat army. The fighting unit is a division. A division will have about 25,000 men, in round numbers, and in it will be one regiment of engineers, sapper engineers, of about 1,600 men. That is the regiment which does the engineering work for the division, excepting for a sapper platoon in each infantry regiment, which is supposed to do certain pioneer work. They have a full and complete engineer equipment of all kinds of tools. They were a little shy throughout our service, because we never had enough horses and not quite enough trucks.

Behind the division comes the corps, which consists of anywhere from three to six divisions, each of which had its divisional engineer troops, and each corps had a sapper regiment exactly like a division sapper regiment, and a regiment of pioneer infantry, largely used to do engineering labor work.

The organization above the corps is the army. The army consisted of anywhere from two to seven corps. Now the corps stays in all the time. It will have two, three or four divisions fighting and others out resting, and it doesn't always have the same divisions. But the corps stays in, and so does the corps engineer and the corps engineer regiment. The army will handle from two to seven corps. Our First Army had as many as seven corps at one time and as few as two at another time. With the army are the army engineer troops which are made up of all classes. There will be a big regiment of highway troops and a battalion of quarry troops to do the road work and get out the rock. There will be several regiments of light railway troops to put down the narrow gauge lines. There will be two or three regiments of standard

gauge railway troops to rebuild the lines which the enemy has destroyed or to repair them, and to build new lines and rail-heads. There will be some foresters to operate the portable saw mills. There will be a regiment of electrical and mechanical troops to fix up the power lines and do all kinds of mechanical work, operate the pump lines, etc. There will be a shop and supply regiment, which puts in small repair shops and operates them and the dumps. There will be a construction regiment to build shelters and to help build railroads, bridge heads, dump buildings, etc. There will be a search-light battalion, which operates the search-lights to protect against bombing expeditions of the enemy. There will be the topographic and flash and sound ranging troops, which make the maps and operates the flash and sound ranging. There will be a regiment of miners. There will be the gas and flame troops. There will be pontoon troops, which may be assigned to the corps, but which go back to the army organization for assignment. There will be a great many labor troops, twelve regiments or thirty-six thousand pioneers, who are engaged in all kinds of pioneer work. There will be attached to an army which will consist of something like three quarters of a million men, something like sixty-five thousand of what are known as army engineer troops. If you have only two or three corps, you won't need that many behind, but for our normal five-corps army, there were sixty-five thousand men under the command of the chief engineer of the army. Behind them in the S. O. S. there are many of these same classes, but they are the troops which are supposed to be doing the work which I briefly described to you as done by the director of construction and forestry.

I can now begin to tell you some of the experiences that I had there. I went over with one of those divisional regiments and in June I was designated as chief engineer of the First Army, which had not then been formed. Only enough engineer troops had been raised to equip one army and the service of supply behind one army. There was one regiment, or one battalion of each organization I mentioned, and some of them were already over there working in the S. O. S. But they had not all gotten over there when the call came for infantry, after the Boche drive of March 21. So that, when this army was ordered to be formed the troops were not in France, that is, the army engineer troops. About a third of them were there, and the majority of the rest were on the water on the way over. This was in August. Those that were in France were working back in S. O. S. and couldn't possibly be spared. They were trying to do three times as much work with less force, because they expected to have them all over there and to be working only to get places ready for about one-third as many men as were coming over. You can appreciate that it was not an easy job getting those troops up from the S. O. S.

In July there were two corps which had been fighting under French command, near Chateau Thierry. That was after

our first drive had started. It was decided that the First Army would take command of those two corps at that point, and they took command, and we had that army of two corps operating there for about ten days. I tried to get enough army engineer troops to equip the two-corps army with engineer troops, and I got only one colonel, his staff, and one company of electrical and mechanical engineer troops. That is all I got during the twelve days, because they could not be gotten up in that time. However, it was decided to move over to St. Mihiel and there they gave us a month to organize an army of three corps to put over the St. Mihiel job. We went over there on August 12, and the attack went over on September 12. That required additional troops over what had been figured behind the other army, so I put in a second requisition and they started them up. There were sixty per cent of those troops there when the attack went over,—just sixty percent. But they got away with it.

But two days before that attack went over, on the tenth, the staff of the First Army was notified that another attack was going over between Verdun and the Argonne Woods. It was going to take three additional corps. And the army in the meantime would also have to handle the three corps which were putting over the St. Mihiel attack. The Verdun-Argonne attack went over on September 26. There wasn't an engineer that was asked for for that attack that got up before the attack went over. We did get some around from the St. Mihiel sector by taking about two-thirds of those troops which ought to have remained there. But the troops came up during the next fifteen days, until on October 10 we had behind the two armies forty-five thousand army engineer troops, all of them draft troops, that is, new troops; there were no regulars among them. There were six officers in that organization, including myself, that had had experience in the army before the war, and all the rest of them were draft troops—but they were good troops.

I want to tell you something about that job,—the second attack. The first attack was not a particularly difficult one, and we had the advantage of having had time to get ready for it, so it went over very smoothly. It was a beautiful piece of work, done by the attacking troops, and it wasn't such a bad piece of work done by the engineers behind the lines, if I do have to say it myself. But we were in no such fix on the other attack, which was really the battle.

Those of you who are familiar with the map can visualize an attack going across between the Meuse River on the right flank and including the Argonne Woods on the left,—the worst pulverized ground in France. That had seen the battle of Verdun, the attempt of the Crown Prince to take the City of Verdun. Half of that No Man's Land was a mile and a half wide and it was plowed as thoroughly as if it had been plowed six feet deep by real plows. You had to make the ground on which to build your

roads. The other half was through the Argonne Woods—almost impassable. We were striking at the vital point of the German communications, and we struck the heaviest resistance that was put against any troops, because they had to hold Mezieres, Sedan and Montmedy, or a portion of the army to the west would have been cut off and captured. They put twenty-three divisions out of sixty fresh German divisions against the American First Army alone, and it was fighting over only about one-tenth of the fighting front. In addition, we had no railroad at all and only one road, with an army of four hundred thousand men to be supplied and a contemplated advance of thirty to forty miles. It was a new army and had no army engineer troops, so it was in a pretty bad fix when it started. We captured a Boche order after we had been operating about ten days giving the instructions of General Von Marwitz to "hold fast." He said, "The Americans have picked out for themselves the worst job of any of the allied armies. They are driving against our bases over the most difficult country, and their flank is not advancing." And he called on his troops to resist to the death. His statement was absolutely accurate, except in one respect, in that he said the Americans had picked it out for themselves. It was not picked by the Americans. But we were lucky in the weather in that drive. If we hadn't had twelve or thirteen days of almost perfect weather that army might not have advanced, but from two days before zero hour until eleven days after we had very little rain, and the engineers were able, as the troops came dribbling up from the S. O. S., to keep up with the infantry attack.

I can remember clearly a remark of Colonel Wooten's. He was chief engineer of the third corps, and he was out there all the time. I saw him one day after we had been plugging along for about ten days and it had not begun to rain. He said, "Well, I crawl into my dug-out there and I hear Woof! Woof! the Boche dropping bombs. I turn over on the other side and say, Thank God it isn't raining! I suppose tomorrow night I will wake up and hear the patter of the rain on the roof, and I will turn over on the other side and thank God the Boche can't come over with his bombs. It is never so bad but what it might be a little bit worse."

On October 10 the First Army was split into two parts, and the old St. Mihiel half of it was given to the Second Army. General Deakyne was appointed chief engineer of that army. He took about two-fifths of our troops, leaving us something like twenty-five thousand men, which afterwards increased to about thirty-five thousand. That took a little of the work off the hands of the First Army.

Then, on October 21, after the machine was running in fairly good shape, it was decided to organize a Third Army, and to make a drive to the right of the Second Army in Lorraine, in combination with some French troops. By this time all of those engineer troops for one army had been gotten across. They were not all up but they were all in France. Others were being organized in the

states, and were in the priority list to arrive in January, February and March, so I was up against the job of organizing the army engineer troops for the Third Army, without having anything to organize them out of except by breaking up the organizations working behind the First and Second armies. There were a half dozen sapper engineer regiments at the rear which had been saved out of replacement divisions, and except for the fact that a couple or three of them were going to be required to fill the casualties in the engineers, they were available. We tried to get the general staff to agree to allow us to transfer into the engineer regiments to fill casualties some of the white infantry pioneers in order to save the sapper regiments intact to use them as the army engineer troops for the Third Army, but they couldn't see it. The general staff officer was going to preserve the pioneers, because he thought they were better than the sappers, I suppose, but, at any rate, I had only three regiments, and I was going to need about ten thousand men. Fortunately—for me at least—the army was not formed. The armistice was signed and suspended all operations. And I must confess I don't know what we would have done for army engineer troops if it hadn't. We would have had three regiments, and I probably could have gotten three regiments from the First and Second armies, but it would not have been enough to do the engineering work behind that Third Army.

It was a most inspiring thing to work about Verdun. Nearly four years ago the Germans started their terrific drive on this old French fortress, and for months the Crown Prince's army battered away with tremendous losses, but the French held fast in a defense that will ever be one of France's proudest traditions. Those of you that know the map will remember that the Germans cut both the railway lines leading to Verdun in the early stages of that attack, and kept them cut until our attack restored them. But the French constructed a line into Verdun from the Southwest, the same line, by the way, which the Thirteenth Engineers have been operating since it has been over there. That is a Chicago regiment. During the entire course of this battle, which lasted for ten months, Verdun was supplied over a highway leading back to Bar-Le-Duc, fifty kilometers in the rear, and all the munitions and all of the food for that defensive garrison went in there by trucks. The French put on that line nine hundred thousand tons of rock in ten months. They had a working force on that road consisting of soldiers on both sides of the road at intervals of five feet, and they worked twenty-four hours a day, in three shifts. That working force lost more men in killed by men being run over by those trucks than any French Division defending Verdun. The French will be singing for all time to come the praises of the defenders of Morthomme, Douamont and other famous battlefields in this circle, but the fact will remain that those soldiers on that road were the men that saved Verdun.

The American First Army went over the top in the biggest

battle which we had in that same area, on that historic battlefield, on September 26, and I gave you a brief sketch of the difficulties with which we were confronted. The work was tough and slow, but the troops came up from the rear just in time to save a hopeless situation practically every time, and the construction work behind that army was able to keep up with the advance of the infantry largely by reason of the fact that the Boche at that sector was putting up his stiffest defense on the whole line. Our advance communications by November 1 had pushed two standard gauge lines of railway beyond No Man's and, and we were carrying four hundred and fifty cars of supplies—about six thousand six hundred tons—over those lines every day. In addition to that we had four trunks of sixty centimeter lines advancing from the old railroads thirty miles, carrying two thousand tons a day. We had restored the old highway and built three others, which were standing up under the lightened truck traffic, because most of the trucks by this time were out operating from the rail heads beyond No Man's Land.

On November 1 the last drive of the American army went over the top, and it was stopped only at the stroke of "eleven" by the clock on the day of the armistice, at the Sedan bridges, and within short gun range of Montmedy. Whether the battle be called Verdun or the Argonne, certainly it will forever remain a bright page in the history of the United States, and the engineers can rest assured that they did their share.

I want to speak about some of the work that those men did over there. I want to mention one or two instances which I think were typical. There was one battalion of one regiment working at Avocourt. There were three divisions going through this town, which was badly shot to pieces. One of them had to have a new road constructed outside of the town, because more than two divisions could not go through. A battalion of the 602nd went in there and the major commanding that battalion worked for three days without going to bed, and his battalion worked sixteen hours the first day and twelve hour shifts the other two days, and they got that road through in three days. In just three days they had a new road constructed over that plowed, swampy land so the third division could get its trucks and supplies forward.

Another regiment went out at half past twelve o'clock at night and started to work at half past one—they had an hour's march to get out into No Man's Land. It went forward with the troops after working for four hours, and they worked on the roads, principally carrying mud and rock and building up roads over which the troops had to advance. The men were given one hour off, and they quit at half past six in the evening after seventeen hours of work, and as the day was finishing, an hour after dark, the men were carrying rock in sand bags into these roads at the run. I can take considerable pride in the work of that last organization because it was the regiment I took over.

Another detachment worked for twenty-seven hours without resting, in order to get a light railway line into an advanced artillery dump at Montfaucon,—twenty-seven hours straight.

What lessons are there for the engineers of the United States from our experience in France? In the first place the work that was done over there was done largely by you men. The number of engineer officers and soldiers of the regular army were vastly insufficient to do the work. It was only by the coöperation of all the engineers of all kinds in the United States that anything at all was done, but I will have to admit that we had a great deal of trouble with a very large number of civil engineers suddenly transformed into soldiers, largely through three reasons: their lack of discipline, which they could not get, even in the three months of training camps; their lack of a knowledge of how to take care of men, and in some cases their lack of accuracy. I think that every civil engineer (I haven't any confidence that this is going to be the last war), after the lessons that we have had, in the slowness with which we were able to get ourselves into this war, should develop and fit himself for military service, making a special study of discipline, of care of men, and of accuracy. By accuracy I mean when you get an order from anybody see that you understand it before you start to do it, and then see that you do exactly what you are told. That is inbred in the military officer by discipline, and by his training, but it isn't any more useful to the military officer than it is to the civil engineer, and it ought to be cultivated. If all engineers had had that as well as the military engineers that we had, we would have gotten along a great deal better.

Another thing which we found difficulty in impressing upon the civil engineer over there was the difference between time and cost in this military work and in his ordinary civil work. Time is everything in our military work and the cost is nothing. You know that it is exactly the reverse of your civil engineering experience, and it is hard to take a man who has been trained to figure his costs closely and take the necessary time to do it in order to get it right, and then have the procedure absolutely reversed so he goes at it regardless of costs in order to save the half hour which may be absolutely vital in the military problem he is at work on. But, as I said before, I will say that we officers who were charged with the military engineering defense of the United States would have been absolutely lost without the wonderful support which the chief of engineers in his work of organization, and all of his subordinates afterwards in their organizations, had from the various engineers and technical societies in the United States. As your retiring president said, "Loyalty to the job is what every engineer feels is his business." The job in this case was to get to the war and finish it up and finish it up right. I think that the engineering societies of the United States appreciated that a little bit more and a little bit better than anybody else in the United States, principally because they were engineers, and they came through with fine support. We

had a tremendous organization in creation. We had really a tremendous and wonderful organization in France. The rest of them were being gathered together. Next summer we would have had a really wonderful assemblage of engineers in olive drab in France, and it was done by you men, and by the other societies, and, as a representative of the chief of engineers and as a representative of the United States Army, I want to take this as occasion to thank you one and all for the help that you have given the national government and for the share that is yours in the celebration of the victory which is now ours.

Handling and Storing Bulk Cement

Presented November 11, 1918.

By Wallace R. Harris,
Engineer, Cement Products Bureau, Portland Cement Association

THE American nation is beginning to realize the need of efficient business methods in every line of industry, and we should never remain satisfied that we have covered the ground fully but always strive for further improvement and for the elimination of waste either in materials or energy. The necessity of saving raw materials is before us today and the saving of paper and cotton can be increased by the elimination of cotton sacks in the handling

Fig. 1. Unloading Bulk Cement from Car

of portland cement. Such elimination would release millions of pounds of cotton which could be used for more important purposes than in acting as a container for portland cement.

It may not be of great interest to the engineer, but it certainly is to the contractor, to realize that the elimination of cement sacks will also do away with arguments regarding counts of empty sacks between the contractor and the dealer or the contractor and the cement mill.

The use of cement in bulk is increasing very rapidly and there are no logical reasons why it cannot be handled economically by dealers and users. It is true that in some parts of the United States local conditions may exist which would require the transportation

of cement in such small packages as the present 94-pound sacks so the packages can be loaded on pack animals and carried over rocky trails, up mountains or across deserts, which would be impassable by wagons, trucks or railways. It may be necessary even to use man-power in carrying cement, in which case a package such as the 94-pound sack is necessary.

The greater part of our construction work, however, is done in districts where such unusual conditions are not found and therefore bulk cement could be handled without trouble. The engineer, of course, is interested in the economical features as well as the construction features involved in the handling of bulk cement, and would want to know what savings would be effected on the sack items, as losses, storage, counting, shaking, bundling, cartage, return freight charges, insurance, interest on money tied up in sacks from the time they leave the mill until they return to the mill.

As a definite indication of economies obtained by using portland cement in bulk, the following tabulation is given and refers to a cement products manufacturer who uses more than 500 barrels of cement a day. In fact, the total consumption is about 200,000 barrels per year.

Saving Effected by Using 500 Barrels Bulk Cement Per Day.

Differential on 500 bbls	at $0.05	$25.00
Labor saved in unloading 500 bbls	at .03	15.00
Saving in cement returned with bags, 3.5 bbls	at 2.00	7.00
Freight and labor saved on 2,000 M. T. sacks	at .01	20.00
Saving in lost and damaged sacks, 5 per cent	at .25	25.00
Interest saved at 6 per cent on money invested in sacks, estimating that sacks are returned each month		2.50
Saving in liability insurance, on labor used in handling sacked cement and M. T.'s at 5 per cent		1.75
Total saving on 500 barrels	at .19¼	$96.25
Saving for 300 days per year at $96.25		$28,875
This saving is equal to 6 per cent interest on an investment of		$481,250.00

Savings on the following items have not been included in the tabulation above: Fire insurance rates on empty sacks in storage or in transit and the rental value of storage space occupied by empty sacks and the rental value of the greater space required for storage cement in packages.

The above saving of $28,875 is gross and to obtain the net saving an estimate should be made on the cost of conveying the apparatus, and proper allowances should be made for cost of power for operation, for maintenance, depreciation and interest at, say, 6 per cent on the cost of machinery installed. No deduction should be made for the labor in operating bulk cement apparatus as the second item in the table above represents the net labor saving, proper

allowance having been made for the labor to operate bulk cement machinery. No attempt has been made to tabulate the costs suggested, as the machinery layout for handling bulk cement will vary in design and cost with the variations in local conditions, but it can be seen that considerable money could be spent on such apparatus long before the savings would be exhausted.

The equipment and methods required to handle bulk cement will vary greatly in character, due to the difference in amounts of cement required as well as to differences in local conditions affect-

Fig. 2. Dumping Bulk Cement from Wagon

ing the work. For this reason several schemes will be outlined below.

In the construction of the Chicago Road, Milwaukee County, Wis., bulk cement was used for the construction of 21,400 square yards of concrete pavement. The cement was unloaded from box cars by two men using D-handle scoops to shovel the cement into tight wagons alongside the car. During the first part of the work the wagon was driven to the point of use and the load was dumped into a shallow bin on the street. From this bin the cement was shoveled into wheelbarrows on the bowl of which was a painted line to indicate the limit of loading. The barrows were then wheeled to and dumped into a charging skip of the concrete mixer. The contractors were so pleased with the savings in money and labor effected, as well as with the conveniences of handling, that they improved their methods by doing away with the storage bins on the ground and using instead extra wagons, which were allowed to stand on the street until the cement was used from them, when the wagons were returned to the car and reloaded. In this way one team

was able to care for several wagons. A steel measuring chute was adopted which was hooked over the side of the wagon or the end of the wagon and into this chute the cement was shoveled. When it was desired to load a wheelbarrow with its charge of cement the upper slide in the chute was closed and the lower slide opened, thereby allowing the cement to flow into the wheelbarrow, which was wheeled to the mixer and dumped into the charging hopper the same as above.

This method of handling bulk cement is dependent upon a clear hauling space along the line of work. A distinct contrast to these simple methods is the construction of a $50,000 plant for receiving,

Fig. 3. Shoveling Bulk Cement into Wheelbarrows

storing and handling bulk cement which will be used in the construction of a dam on the Tennessee River at Alcoa, Tenn., and which will require a total of about 500,000 barrels of cement.

The illustrations accompanying this paper indicate the principle details of design, and it will be noticed the plant is so constructed that two receiving tracks are provided, thereby allowing the unloading of two cars of cement simultaneously.

Power shovels are used for this purpose and the cement is unloaded into the receiving hopper of the bucket elevator which deposits the cement into receiving chutes and also into a screw conveyor which distributes part of the cement to other receiving chutes. This arrangement allows the bulk cement to be evenly distributed throughout the storage bins. By using a deflector at the discharge chute of the bucket elevator, the cement can be deposited into another screw conveyor leading to the concrete mixing plant. This arrangement permits cement being taken directly from the cars and conveyed to the storage bins at the concrete mixing plant without storing in the main storage bin.

When, however, it is desired to take cement from the main storage building, delivery chutes are opened in the bottom of the central storage space. The cement flows into a screw conveyor and is carried to the bucket elevator mentioned before, raised to and deposited into the screw conveyor leading to the concrete mixing plant.

Portland cement becomes firmly compacted when the entrapped air is released and a reduction in volume is equal to as much as 25 percent will occur. As the slope of the hopper bottoms of the storage bins is not sufficient to overcome the arching action of the cement, means must be taken to break up the arching and

Fig. 4. Handling Cement Direct from Wagons

to cause the cement to flow easily. The compacted mass of cement can be converted to an almost fluid condition by the introduction of air under pressure, and this can be accomplished by placing air pipe lines one-half inch in diameter, on 24-inch centers, the lines being laid on the hopper bottoms of the bins and also on the bottom of the central storage space in which the delivery chutes are located. These air lines are provided with 1/32-inch openings on 6-inch centers and each line is encased in a sheath of four-ounce canvas sewed in the form of a tube. This canvas sheath is wired to the ½-inch pipe by wire tires placed on 6-inch centers midway between the 1/32-inch outlets. An air pressure of 80 pounds at the compressor would be found sufficient to create a flowing condition in the cement.

Although in one installation, no provision is made to remove moisture from the air, yet under some conditions it may be necessary to provide dry air for this purpose.

The cement is contained in a temporary bin of comparatively small capacity at the concrete mixing plant. This bin is provided with delivery chutes for each one of six 2-yard mixers, the machines being arranged in two batteries of three mixtures each.

As the use of bulk cement increases, the greater will be the

demand for efficient economical means of measuring or weighing the quantity required for each batch of concrete. Several manufacturing companies have this matter in hand and some of them have machines applicable to this class of work now.

Measuring devices similar in nature to that used on road construction have been, and will be used to some extent in the future, and it would be advisable wherever measuring and not weighing devices are used, to make tests to determine that a certain cubity in the measuring chute will contain the required weight of cement. For instance, the writer believes that in a chute arranged to measure two sacks of cement, or 188 pounds, that a chute of one foot square cross section would have to be approximately 2.25 feet in length between the sliding gates.

In work where a steady consumption of cement is maintained, and the quantity used runs into many thousands of barrels, a weighing device will probably be found more certain and more economical in action and operation. The same will apply to large construction work, even though the construction plant may be temporary in character, such as described above for the Alcoa dam.

It should not be assumed from what has been said that unusual or unsurmountable conditions exist in the handling, storage and use of bulk cement, for although it is recommended that the design and construction of such plants as has been described for large construction work, should be left to qualified engineers, yet the information now available is such as will prevent mistakes in installation design. It is to be hoped, therefore, that all construction engineers will consider the economical advantages of bulk cement and stand ready to assist in making the American nation the most efficient in the world.

DISCUSSION.

O. F. Dalstrom, M. W. S. E.: What is the effect of exposure on bulk cement as compared with bag cement?

Mr. Harris: You will find less deterioration from bulk than sack cement because in sack cement you have the spaces existing between the sacks allowing circulation of air, whereas bulk cement will allow the entrapped air to escape quickly. Bulk cement becomes so firmly packed in a car that you can walk across it without sinking in more than a quarter of an inch. On that on board ship at Great Lakes you don't even sink a quarter of an inch and it would take a pick to loosen it.

In the case of a leak in the bottom of a car the arching of the cement is evidenced by a hole in the bottom that will allow the cement to come down in a narrow funnel shape.

In the case of a leak in a car roof the moisture will penetrate and form a ball there which will still absorb the water. In the case of a carload of sack cement the cotton or jute will soak up the moisture and allow the cement to set to a certain extent. The rain will drop on that and spatter over the entire end of the car. I have had cars where the cement was badly spoiled due to one

or two leaks in the car. I have found a good many users of bulk cement surprised at the small amount of damage, even when leaky cars were used, in shipping bulk cement.

The Chairman, G. A. Haggander, M. W. S. E.: We had about 7,000 barrels of cement to be used in building a big bridge in Wyoming. This bridge was about 100 feet high and we had a very fine opportunity to build a central mixing plant at one end. We built bins under the trestle-work and expected to dump our

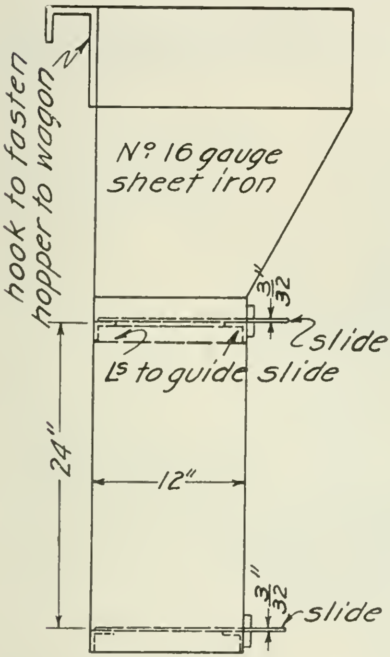

Fig. 5. Device for Measuring Bulk Cement. Unloading Hopper for Wagons and Trucks.

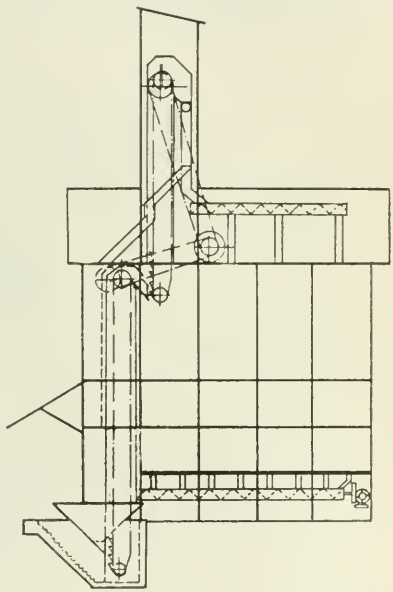

Fig. 6. Longitudinal Section Illustrating Plant Layout

cement into these bins and from there into the mixer and culvert. We started out by getting twenty carloads of bulk cement. It was hauled nearly a thousand miles and when it reached the destination it was packed very hard. It had to be spaded down before they could shovel it, and we found it took ten men about three and and a half to four hours to shovel out one car of that cement. That seemed a very long time.

This was our first experience and the men were not accustomed to it, but it took about ten men three and a half to four hours to unload one car.

Another local condition there which caused trouble was the wind. We had wind out there sometimes thirty or forty miles an hour and continuous for long periods of time, and the men com-

plained a good deal. They couldn't hardly work in the car with the bulk cement on account of the wind blowing all the time. We finally changed to sack cement and it seemed to be handled much more easily on that particular job. We could unload a car in thirty to forty minutes with the same number of men. It seemed to us that the cost of sacks and other expense would more than pay for the cost of unloading and handling. We found a scoop shovel was almost too large. They couldn't handle a scoop shovel; a coal shovel was too small.

Mr. Harris: Mr. Haggander states that the long travel occasioned with that cement caused all of the air to be driven out and

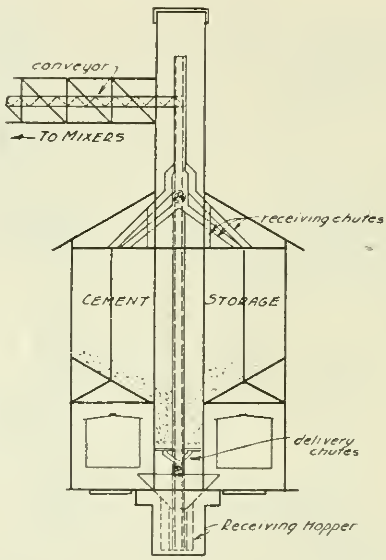

Fig. 7. Cross Section Diagram Illustrating Plant Layout

the cement became very well packed, so much so that I doubt if a man would sink into it at all but could run across it the same as on a shingle beach. Today I doubt if we would have to ship cement that far. It would be impracticable probably to attempt to fit up cars especially for connection with air, to break up that compacting.

The packing of cement is similar to what is often experienced in transporting cement. It has to be picked out with picks, shovels, and so forth, and it was thought for a while it would almost have to be blasted out. This air system was used and it solved their troubles in a very short time. The air penetrates the mass and gives the appearance of something alive working in the cement. It simply works right up through it and the whole thing is fluid, so it would be dangerous to walk across it. Since the air was installed no trouble has been found.

Based on my experience in construction work, I would not use an ordinary handled square point shovel nor a coal scoop, but a pointed sand scoop, the same as I have furnished to men in loading gravel on piece work and with which one man of forty was able to load two carloads of gravel in sixteen hours. There were other men in the outfit who could only load one car and one gang of three men could only load two cars between them in a day. That would indicate that one must have the tools and the men back of the tools when it comes to manual labor. I believe, on the work that Mr. Haggander states he had so much trouble with, that if one of these heavy pointed scoops, with which you would get a

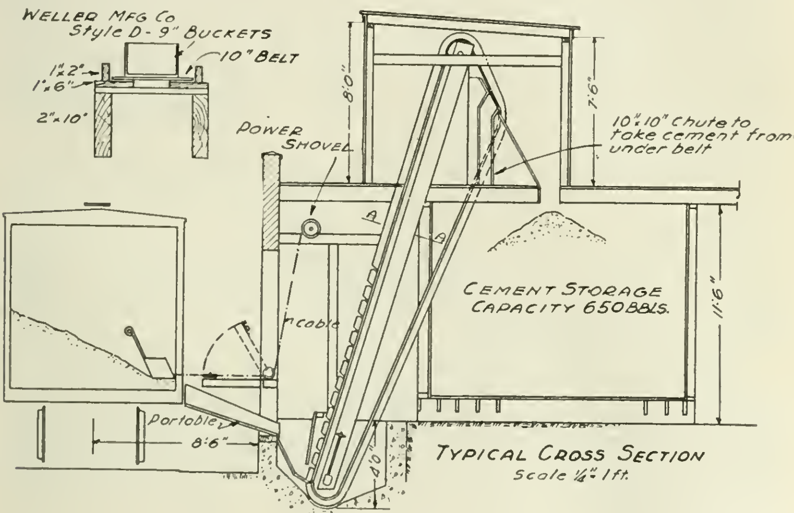

Fig. 8. View Showing Arrangement of Power Shovel Used to Unload Bulk Cement

shearing action in going through the cement, had been used, they would have had less trouble.

The Chairman: How long does it take to unload a car of cement with shovels if it is not packed very hard? Fig. 1 showed the cement being unloaded into wagons.

Mr. Harris: On that work it takes two men about six to eight man hours. There was a certain amount of lost time in that case between teams coming up, taking away a wagon and spotting another, but the average is six to eight hours. It would take all day or a day and a half to unload a two hundred barrel car.

The Chairman: That would compare favorably to unloading sack cement handled about the same, wouldn't it?

Mr. Harris: Yes. In that they used a scoop which would not be as heavy as an ordinary furnace coal scoop used in a power plant; it would be smaller than that.

The Chairman: Does the dust bother much under ordinary conditions?

Mr. Harris: Those men do not use respirators and the contractor states that he has no complaints from them, or very few complaints, but I believe he would have had better results if he had used them.

Mr. Dalstrom: How is the air appplied?

Mr. Harris: There are distributing lines which would contain 1/32-inch outlet openings on 6-inch centers, the entire pipe being in four-ounce duck, which is light enough to allow the air to come through and still to diffuse. The idea is not to shoot a jet of air through the mass of cement but to furnish enough air under sufficient pressure to cause it to become diffused throughout the mass of cement. That is done with eighty-pound pressure and by distributing it through these small 1/32-inch openings covered with the four-ounce canvas. To prevent the canvas bellying too much they have wired it over every hole.

The Chairman: What kind of a house would you have for storing cement? Would it not be desirable to have an air space between the cement and the outside ceiling?

Mr. Harris: As an engineer I would be in favor of an air space; as a contractor I would probably forget the air space. They usually build up a cribwork of six-inch lumber laid flat, crib it up and put the cement in that.

One point that it might be well to bring out is that the discharge of cement from the storage bin should be centrally located so that you will not get an avalanche action by taking the cement from one corner of your bin, but take it from the center so the cement will fall from all sides to the center whether the bin be square, rectangular or circular.

Mr. Nethercut, M. W. S. E.: How much bulk cement is being shipped at the present time, in comparison with the bag cement?

Mr. Harris: That I cannot say, but within three months we had reported the use of approximately three million barrels of cement in bulk, not including a million barrels prospect for the United States Government, which will be used though the work is somewhat delayed. That would be four million barrels in a little over three months, I believe it was.

Mr. Warren: One company, the Universal, shipped as high as five or five and a half per cent bulk cement last year. This year it is something under that. There are more users than ever before but the total volume is lower than in the past—possibly three or four percent. This would cover Pennsylvania, Ohio, Michigan, Illinois, Indiana, Wisconsin and Minnesota chiefly.

Automobile Power Plant

Presented April 23, 1918.

By C. F. Kettering,
President, Society of Automotive Engineers.

NO subject today is of greater interest than the internal combustion engine. There is a great deal of misunderstanding and misapprehension regarding it and it might be of interest to consider what this very useful piece of apparatus really is. The internal combustion engine is the first instance in the history of mankind in which we have had a prime mover of relatively large power and small weight. The greatest advance which civilization has made is due largely to our ability to use inanimate power. The cities have developed wonderfully because of the centralized electric-light plants, and so common is the use of power from an electric source that one does not think anything about it any more. How many people ever think, when they turn on a motor in the shop, where the power really comes from? Very few people ever give a thought to the steam turbines or the water wheels that are furnishing that energy. We say it is electric power, and we stop there. It is steam power or water power, and the whole subject of electricity is only a transmission device, a flexible belt, so to speak, but it is so flexible that it can run around corners to almost any place wanted. We have forgotten to take into consideration the point of origin.

But in the internal combustion engine we are given an opportunity to witness a fundamental prime mover; and that fundamental prime mover has made it possible for us to have the automobile, the tractor, the airplane, to have the motor boat and a thousand and one other devices which are dependent upon the very simple and very interesting piece of mechanism called the internal combustion engine. We have learned to consider this engine as a fixed thing of pistons and cylinders, and it will be of interest to pull that engine apart and see just why it is. If one can remember the time when we had eight or ten horse-power engines with large flywheels, he will remember that we did not get very good results. Then the electrical man came around and told us that we ought to get that engine out of our plant, if we did not want to shut down the shop; and he was very nearly right at that. Yet, I venture to say, there is no electrical man in the audience who will try to produce an electrical motor today that will equal the achievements of the internal combustion engine.

Now, there is nothing mysterious about it, but it has been made a mystery in a great many cases. Who was it who wrote that classic about the motor boat engine? And the thermo-dynamics of these engines have been more or less confused with the intricate calculus sign. It might be of interest for us to analyze the prin-

ciple from a slightly different angle than the one customarily employed.

There are various kinds of internal combustion engines. Practically every member here knows the difference between the four-cycle engine and the two-cycle engine. We all know the difference between the internal combustion engine used on the automobile and the Diesel engine. Up to the present time, the internal combustion engine has been regarded as a fundamental mechanical device, because we have had such elegant fuels that we have been able to neglect the fuel element entirely. But, at the present time, the fuel question demands consideration. From now on, in the design of internal combustion engines, we will have to take into consideration more factors than we ever did before, for the reason that a great many of the things which have to be considered now were formerly not present because of the better grade of fuel available.

In the discussion of a heat engine, we need primarily to get fixed in our minds something of the meaning of the word "temperature." We are so prone to hitch up these terms with our physical senses. When a man says something is hot or something is cold, does that convey a distinct idea or is it a condition which is only noticeable to the sense of feeling? I always like to look upon temperature or variations in temperature as simply relative movements, and I think that, if we will take as a basis that heat and cold are only representative terms, which state the rate of movement of the molecules of the substance, we will get a great deal better appreciation of temperature. We know that we can put our finger against a red hot stove and burn it. We also know that we can stick our finger into liquid air and get a bad burn. We also know that we can stick our hand against a grindstone and get the skin scraped off, or one can fall on the sidewalk and do the same thing. So that, as far as an energy transfer relation is concerned, it makes but little difference whether one sticks his finger against the red hot stove, the stove moving faster than the finger, or whether the finger is thrust into liquid air, the finger in this instance moving faster than the liquid air. The result is about the same as falling on the grindstone in the one case and falling on the sidewalk in the other. We thus get something of a physical conception of what temperature is, and it helps us to analyze the internal combustion engine.

Fundamentally, an internal combustion engine consists of a cylinder, a piston and valves. The crank-shaft and the cam-shaft, etc., are only the auxiliary mechanism that have to be put on it. So far as considering the major part, or the power-generating part of an internal combustion engine is concerned, we are interested primarily with the cylinder, the piston, and the valves. The rest of the mechanism is only the power take-off.

Consider it that way for a few moments and we will get another interesting conception of the engine. If we compress a mixture of any fuel whatsoever in the right proportions with air, ignite it,

and start it burning, the pressure is increased rapidly. In the increase of these pressures, if we allow the piston to move, mechanical work is taken off. If we hold the piston still, the pressures go up and remain so until the entire energy of the charge is absorbed by conduction through the cylinder wall.

Looking upon the impact against the cylinder head as a $\frac{MV^2}{2}$ function of those molecules of burnt gas being tiny projectiles shot against a piston head, we will get, fundamentally, the idea of pressure developed by burning gases, and will also be able to appreciate why there is a fixed relation between the rate at which a piston gets away from its burned charge and the rate at which the energy is conducted out through the cylinder walls. In other words, the point I want to make is that, if the piston is held and prevented from moving, useful work is not secured from that charge; but if it moves, useful motion results.

The efficiencies which you get from the rate at which the piston moves are not so marked in the ordinary automobile engine driven around the streets as it is in an aviation engine, where we are struggling for the last ounce of power and the highest degree of economy we can obtain.

There is a great deal of discussion, both pro and con, as to what the mixture in a cylinder should be. For that reason, there are carburetor devices, manifold devices, etc., being developed. In order to get the one point of carburetion clearly, one must keep in mind the single cylinder engine, because, regardless of the number of cylinders put on any one crank, the principles involved are embodied primarily in the individual cylinder. In developing a type of engine, a great deal better idea of what the engine is will be obtained if the experiments, up to the time the true engine has been developed, are confined to just one cylinder, because a set of very complex problems of distribution, valve timing, etc., are introduced when a number of cylinders are combined. There are a lot of notions that, if a fuel is taken into a cylinder in an atomized or in a liquid state, the efficiency is not nearly as good as if taken in the form of a dry mixture. With very few exceptions, it makes absolutely no differenece how the fuel is taken into the cylinder. It can be taken in wet, dry, or in any other way, for after the engine has reached its normal running temperature the number of heat units required to change the fuel for a single charge into vapor is so insignificant, compared to the available heat units that the fuel can pick up from along the cylinder walls, that the form of the fuel is a matter of indifference. The whole subject of carburetion has more to do with the proper distribution of the fuel charge to from four to sixteen cylinders than it has to do with an exact combustion of that mixture when it is put into the cylinder.

Some very interesting tests have been conducted in the last year or so in studying fuels and fuel mixtures. It is a surprise to most engineers when they find they can take a cylinder of any engine

combination and deliver a little more power out of that engine, taken as a single cylinder engine, than its proportionate part when put into a multiple engine. That is, if a single cylinder engine gives twenty horse-power, and eight cylinders are put together, one would naturally think that they would furnish better than one hundred and sixty horse-power. One might think that one poor cylinder working alone does not have as good a chance to work as when it has a lot of friends working beside it. But as a matter of fact, there would not be one hundred and sixty horse-power, because an absolutely definite, measured quantity of fuel can be delivered to the single cylinder engine through the simplest type of a mixing valve. It can be measured exactly. Therefore, better efficiency can always be obtained, and a little bit more power gotten out of the engine, when running as a single cylinder than when running as a multiple cylinder. In designing an engine of any kind, to determine what is the best cylinder, what is the best valve timing, the best valve ratio, do it on one cylinder.

Now, let us consider the compression of the charge again. Just for the sake of getting clear on this subject, I am going to discuss primarily the four-cycle engine, and I am going to go through the four cycles of a four-cycle engine so I will be understood when I use certain words. We will suppose we have a closed vessel and it has two simple valves in the top. The valves are pushed open at certain definite times. We will suppose the piston is clear to the top of this vessel. One valve, which communicates with the atmosphere and has a means of mixing fuel with the atmosphere, is pressed down. When the piston is pulled down, a complete change of air and fuel is sucked into the cylinder, until there are just as many cubic inches of fuel in there as the space will hold. When the piston is pushed up, the mixture is compressed and also heated some, due to the energy of compression. Then if the mixture is ignited it burns, the pressure increases, and if allowed to move down against a resistance, so many pounds of energy will be delivered to the piston. If, when the piston is down at the bottom of the stroke, it is pushed back up, it pushes the major part of the burned gases out. Then if the intake valve is opened and the piston pulled down again the same cycle will be gone through again. Now, looking at the gas engine cylinder, with its attendant piston, exactly as at a gun, another very important relationship will be seen. In every piece of artillery developed, after the bore and the stroke of the gun, which are the caliber and length of the barrel, have been developed and the weight of the projectile determined, a powder must be developed which burns at the right rate to give the maximum velocity to the projectile when it leaves the end of the gun barrel. The conditions involved in an internal combustion cylinder are exactly identical. Engineering, up to the present time, has stopped, to a large extent, when the mixture was delivered into the cylinder and exploded.

Now we must try to find out what happens in that cylinder

when the explosion takes place. It is only a chemical reaction, and a chemical reaction is governed more or less by certain things. The first is pressure. We know a combustion mixture will burn faster under pressure. Chemical action will take place with an increase in temperature, as a rule. Many things will not react at all with cold. There is pressure and temperature. The next is the percentage of dilution, that is, how much other stuff outside of the explosive mixture is present. So there are the pressure, the temperature, and the dilution factors as the principal elements involved in an internal combustion engine. Then there are other things which play a very important part in some internal combustion work. When the compression of an internal combustion engine is increased, the combustion takes place more rapidly with an increase in the temperatures, and because it does take place more rapidly, the dilution factor does not enter into it so much. Therefore, a very rapid burn with a very sudden rise in pressure and a very high temperature results. So, to get real good efficiency it is necessary to let the piston travel pretty rapidly if you are going to run a high-compression internal combusion engine, where the mixture is taken in and compressed as a whole.

Here is where one of the fundamental differences comes in between the ordinary type of internal combustion engine and the Diesel type. In the Diesel type, the air is compressed to a high pressure and then the liquid fuel is squirted in, while with the ordinary type of internal combustion engine, the mixture of air and fuel is taken in and then compressed. This difference between them should be remembered, because it might be asked, "How do you account for the increase in efficiency from a relatively slow running Diesel engine, when you say that as you go up into higher compressions you ought to let the pistons move faster to get maximum efficiency?" In the Diesel engine the air charge is compressed, up to six or seven hundred pounds if desired, and then the fuel is simply forced in by mechanical means. The temperatures are sufficiently high that combustion takes place instantly, due to what might be called the concentration factor. So the ignition is not needed; the compression is simply run up to the right point, some fuel is squirted into the cylinder and combustion takes place. A long burn can be obtained, if wanted, depending on the percentage of injection. Yet it does not pay to carry the combustion too far, because the expansion of the burnt gases should be used.

Now, to differentiate at this point, because there is quite a diference when considering an internal combustion engine, in which the charge as a whole is pulled in and compressed, instead of compressing the air and then admitting the charge of fuel. This difference is very important for the reason that, for the first time in our lives, we have come up against the fuel question. Up to the present time, the measure of a good fuel has been regarded as one of volatility. Now, volatility has absolutely nothing to do with

fuel, for I can give you as rotten a 76° gasoline as any 48° stuff you ever got.

The power end of this engine will be discussed for just a minute, because all the factors must be considered. It is not a complex problem when the factors are arranged in their right relation in the mind. The only thing done, when a specific-gravity meter is put into a can of liquid, is to measure the average size of the molecules; that is absolutely all it amounts to. A bushel of potatoes can be sold and guaranteed to be of a certain average size. Some of them will be large and some of them will be small, yet if weighed and counted the number of potatoes would average up to a certain size.

All of the fuels that we are dealing with in any internal combustion engine today, eliminating alcohol and rum from molasses used in Cuba, are hydro-carbons, and the simplest of those hydrocarbons is known as CH_4, normally a gas. Going back to elementary chemistry, and considering the carbon fellow as having four arms, each with a chemical affinity of one, and hydrogen having a chemical affinity of one, that CH_4 can be considered as having a center of carbon with four particles of hydrogen attached to its four arms. That is the most elemental type of a hydro-carbon we can have, and it is by all odds the most wonderful fuel that nature has given us. This gas can be compressed to a tremendously high pressure before it shows any signs of liquefaction. It has a B. T. U. value of from 900 to 1,100 B. T. U.'s per cubic foot. From this same series a whole lot of combinations can be obtained. That is, carbon will unite to a certain extent with itself, so that instead of having a hydrogen particle on each arm, two carbon arms will link hands together, and two other carbons will catch hands, and you will have hydrogen on the other arms only. Dozens of combinations of carbon elements can be linked up that way.

There is a simple paraffin series of hydro-carbons represented by the formula $C_n H_{2n+2}$. That seems complicated, but there are two blank arms to each carbon particle, and there must be two at the end. In the gasoline of today is any number of carbon atoms, from five up to twenty-one, united together to form different gravity fuels, and yet when the whole conglomerate is mixed together the average is about the same. When a specific-gravity meter is put in the mixture we say "That is good, 62 degrees." The conglomerate gravity of a mixture has nothing to do with its value; a lower specific gravity, with the potatoes all the same size, is to be preferred.

If simple CH_4 (methane) is taken, it can be compressed up to a very high pressure before it shows any signs of liquefying. Coming down to C_2H_6, about the same condition is reached, but coming on down, making the molecules larger and larger, it takes less pressure to cause them to liquefy. Here is a very interesting observation on fuels which is really the principle which is of interest to everyone. Taking a cylinder full of gas, like natural gas,

and commencing to compress it, the temperature and the pressure are increased, and the tendency toward liquefaction will be a coördinate proposition. There is a tendency to liquefy, and going up you get farther away from the liquefying condition, because the temperatures are increasing and the tendency to not liquefy, due to the increase in temperature, is more than a tendency to liquefy due to pressure. Then, coming down in heavier hydro-carbons, the tendency to liquefy or not is just about equal. Again, as the hydro-carbons get still heavier, you get an increasing tendency to liquefy. Therefore, if certain vapors are taken, put in a cylinder and compression started, the tendency to liquefy increases more rapidly than the tendency to gasify, due to compression. That is why it is so important to know about the fuel or the powder one is going to shoot the gun with. These liquefying difficulties are particularly noticeable in cold weather, as is evidenced by the condensation of kerosene in the crank case and the necessity for frequent draining thereof.

That is why we want to know something about the specifications of fuel. If we take a mixture of casing head gasoline, which is the semi-saturated product of natural gas that comes off the ordinary gas or oil well, and some of the lower order of fuels, and compress the mixture and cool it, it can be liquefied. Now, that very volatile material can be mixed with kerosene and a nice average gravity obtained; some pea potatoes and some big ones mixed together. When this is pulled into the gas engine cylinder, no matter how good a carburetor is on the engine, when the compression reaches a critical point, which for kerosene vapor is about fifty-five pounds, the vapor is going to liquefy and run down the cylinder walls. So it is quite evident that it does not matter what the gravity of the fuel is; so long as there are heavier hydro-carbons present, they will liquefy. It is not sufficient to deliver to the engine a perfectly dry mixture unless there are means of keeping it dry until it burns. When a heavy hydro-carbon is compressed, it precipitates itself onto the cylinder walls, and therefore it is necessary to have, sitting around on the walls of that cylinder, a little reserve bunch of B. T. U.'s, so they will immediately kick that stuff back into gas.

Now, here is the whole story. We are coming up on compression, and we are going to compress that mixture up to where we reach the critical compression, very close to the top end of the stroke, and when this fuel takes a notion to form into dew it is just a very short time before the spark catches it. Therefore, the reserve guards that are sitting on the cylinder walls must work quickly. When the composition starts to burn, the temperature and the pressure go up and the maximum rate at which heat can be put into the little dew particle over on the cylinder wall is a function of the temperature and the pressure and its ability to conduct heat, or what is called its specific conductivity (heat). About the only thing that it does is to decompose. That means

it simply cracks into carbon and hydrogen, leaving a little spot of carbon on the wall of the cylinder.

There may be only one spot the size of a pin head. That is the only spot in that cylinder that was not able to furnish enough B. T. U.'s to kick the fuel back into the mixture. The little pin-head spot contained one little drop of dew, and when it burned, the combustion and the pressure were so rapid that the little particle of dew did not have time to get into the vapor form and so was bursted and left a little carbon spot right there. Now, when the piston comes up the next time, see what a beautiful thing has been accomplished! That little spot has been insulated with one of the most perfect of insulators. The next time the piston comes up that little spot has been insulated from its supply of heat units. A good cooling system must have the ability to shoot the heat back into the cylinder as fast as it takes it out. Now, a little more dew is formed there and, in addition, a perfect sponge put in to soak it up, so that little drop of dew just crawls in back behind to make room for the next one, and the scab forms and keeps on forming until a beautifully carbon-coated cylinder results. Everybody knows that carbon makes a motor knock. Every man has had the experience of having the motor knock when it was absolutely cold. And he says that the reason it knocks is that the red hot carbon is carried over to the next stroke and explodes the mixture too early. That is not the reason at all. The reason is that the motor is too cold. It does not matter what kind of a car it is or what kind of a carbuertor there is on that car. I am talking about vaporization due to the precipitation of the already vaporized fuel on the cylinder walls. The big fuel problem today is: What can be done to supply the B. T. U.'s necessary to keep the fuel in a vapor form on the last few inches of the compression stroke? When the carbon is burned out, the cylinder walls are cleaned off and the water jackets take heat in and out again in good shape for a little while. Dozens of cylinders have been purposely carbonized to see the result and make observations.

Today, in designing an engine, the designer must take into consideration what it is going to be used for, how it is going to be used, and what fuel is to be used. There are many other things that might be mentioned also, but one important problem is; regardless of how the fuel is taken into the cylinder, if a lot of lower gravity fuel in there is mixed with the higher gravity fuel, the lower gravity material is going to precipitate out and form carbon. If the motor could be made with a thin water jacket and a very small water capacity, and, when the engine is first started, the radiator cut off entirely, the temperature could be regulated by an automatic by-pass over the radiator, or some similar device. I think a little later the whole cylinder, engine and all will be completely boxed up, so that inside of ten or fifteen seconds after the engine is started it will be hot. The thermal capacity must be so arranged that it runs hotter at no load than it does at full load. This is exactly the problem,

and it is not a complex one, because the engine can be so made that when the throttle is wide open you can automatically open the by-pass so as to make the circulation work better.

Up to about two or three years ago, fuel was so volatile that it never reached the point of condensation under any condition. The rate at which fuel burns should be a function of the rate at which the piston moves, so that is another thing to be taken into consideration. If the piston is going to move rapidly, we have to raise the combustion rate so that the fuel will burn rapidly; and if the piston is going to move slowly, we have to lower the combustion rate so it will burn slowly. The reason I am mentioning this is because the idea prevails that all of the trouble is with the fuel, and we condemn the producer of the fuel. We are going to have to take just what we get for fuel. The only thing that is going to stay constant in the fuel proposition is the air, and that is going to remain about 20 percent oxygen and 80 percent nitrogen.

There is a tremendous difference in fuels. A lot of people come from San Francisco and the coast and tell how they can run the engine on distillate out there and they come here and try to run the same engines on kerosene and they fall down, although the specific gravity of the best kerosene here is a little better than their distillate out there. The reason for this is that in the making up of these hydro-carbons, nature has performed some nice little tricks. There is a compound present in California Oils, C_6H_6, which is nothing more nor less than benzol, which is used in making up a lot of explosives and various other things. This is what is called a Ring compound, and the beauty of it is that all the particles are exactly the same size. Therefore, California distillate or kerosene, or anything that has an appreciable addition of this compound in it, is a better fuel than another fuel which shows a better gravity, because these molecules are all the same size. I just wanted to emphasize the point that gravity means nothing at all. Synthetic fuels have been produced experimentally that will make an internal-combustion-engine diagram conform to your predetermined wishes.

The cycle of the piston movement can be made with a long compression and the explosion so placed that the fuel will burn well and slowly and keep the push down to the end of the stroke. But the conditions must be taken into consideration during the design period. If an automobile engine is being built there are certain conditions to satisfy, and if a tractor engine is being built there are certain other conditions to satisfy there, and the same with an aeroplane engine. Today, an analysis must be made of what the service of this particular type of engine is going to be.

Perhaps the most interesting thing of the present day in internal combustion engines is the aviation motor, because it is in the limelight at the present time. In this connection, in the Liberty Motor, the United States has the most wonderful aviation motor that the world has ever seen.

Every different type of internal combustion engine has its own problems. The problem of the internal combustion engine as applied

to the aeroplane consists of two principles: First, the matter of weight per horse-power; and next, pounds of fuel per horse-power hour. In other words, weight and economy. It is not sufficient to make a motor which is very light in pounds per horse-power if the efficiency of that motor in the use of fuel is not good, because it is no use to carry a light motor and a big weight of fuel; the aeroplane has to carry them both. We are interested in getting the minimum weight for a given trip, and it would be much better to make the motor a little heavier if it did not consume quite so much fuel.

Now when it comes to a discussion of aeroplane motors, there are so many different kinds of aeroplane motors that it is hard to classify them. They may be split into two classes, one called air-cooled and the other water-cooled. Air-cooled motors are very satisfactory up to one hundred and sixty horse-power. One may say "Why cannot you make them big?" They can be just as big as desired, but the matter of making air-cooled motors large is rather a matter of the congestion of the parts. The parts must be far enough apart to get air between them, and when the cylinders are put close together, satisfactory air cooling is difficult. It is a matter of congestion of parts that limits the horse-power of the air-cooled motor.

One of the motors used on the other side, and known as the "A. B. C.," is an air-cooled motor. It is a radial motor, but the cylinders stand still. Probably everyone knows that in the "Gnome" motor the crank shaft stands still and the cylinders rotate around the crank shaft. Copper cooling fins are fused onto a steel cylinder, and a cross section of one of the cylinders would show a steel sleeve with the copper fins attached to it. Those are rather interesting motors. One 2-cylinder motor, complete with carburetor and motor shaft, weighed 78 pounds and gave 52 horse-power at 2,000 R. P. M. The fuel consumption of that motor is close to 0.43 pounds per horse-power hour; the ordinary automobile motor driven arund the streets here gives a horse-power hour with about a pound and a half consumption, but that motor runs on a consumption of 0.43 pounds, and on less than 0.01 pound of oil per horse-power hour. That is the type of fabrification found when working with the aviation gang.

The "Gnome" motor is air-cooled, but the "Gnome" motors that are used in large quantities are rotary motors. There are two limitations to the rotary motor. It is difficult to produce for one thing. It is also difficult to balance a motor like that. Next, a certain number of revolutions per minute cannot be exceeded because the centrifugal force becomes so great that the gas mixutre and the mechanical factor of safety begin to be affected. Fourteen hundred revolutions per minute is a pretty high schedule for one of them, but when the motors are stopped and the shaft rotated, resulting in a fixed radial motor, the speed can be pushed right on up again.

It is hoped to get about 360 horse-power out of the nine-cylinder "A. B. C." motor at about 540 pounds, at a revolution of about

two thousand per minute. That is just briefly the air-cooled proposition. An air-cooled motor is just as good as a water-cooled motor, but the limitations of cooling must be known. If there ever was a place in the world where an air-cooled motor ought to be satisfactory, it is in an aeroplane, because there never is any trouble in running it idle up there without a breeze.

A discussion of the different types of air-cooled engines might be interesting, but we would get into technicalities on that subject. I am going to pass over to the water-cooled engine. It must be remembered that the gas engine is a cylinder and a piston and a pair of valves. There have been a great many kinds of water-cooled engines designed. The best one is the "Hispano-Suiza." Imagine a cylinder block made of aluminum, bored out, and after the cylinder is bored out, threads cut the entire length of those cylinder bores; then a nice steel sleeve threaded all the way up is screwed up into the aluminum cylinder; then some of the construction technicalities are understood. Now to find out if that sleeve fits tightly all the way up or not Prussian Blue must be inserted and the sleeve screwed up, and then unscrewed again, to determine contacts. But the "Hispano-Suiza" motor is one of the most successful, at that. It is built in the 120, 180, and 300 horsepower sizes, all eight-cylinder motors.

Practically all of the other types of high-powered motors have given way to one type of cylinder, almost universally, and that is the steel cylinder with one end closed, and with valves and a thin welded-on water jacket. The cylinder is flanged and bolted on to the crank case. The valve guides and the ports are welded in. This is the type that is most used and was first built and produced by the Mercedes Company. The method used was to bore away all but about 14 pounds of a 112-pound billet of steel, until the completed cylinder was obtained. Then the water jackets were pressed up and welded on. You will probably now begin to get some idea why an aviation motor costs so much. That motor is used by the Germans in their aviation motors, is used by the Italians, by the French, by the English and by us in our Liberty motors.

The Liberty motor is not a new thing,—not at all. The way I see it, it is simply a glorified American "Mercedes" motor. It might be of interest to those who have watched the auto races to know that the cars that won the races were equipped with motors from the Mercedes plant. It was simply their way of finding out what kind of a motor we had over here, as a possible means of assistance in winning this war. They knew very well when they went into the war that they had the best motor in the world, because it skinned everything on the race track.

Of course there have been modifications made on the Liberty motor to meet the American manufacturing conditions. It is essentially a steel cylinder, five by seven inches, with an aluminum piston and large steel valves. Twelve cylinders are set on a crank case, cranks shaft and cam shafts hitched to them and the motor is com-

plete. The same cylinder can be put on a four-cylinder or a six-cylinder or an eight-cylinder motor.

At the beginning of last year the English had about thirty-four different types of motors on the front and the French had about thirty, and you can well understand what the difficulty of repairs and the supplying of repair parts must have been. The idea with the Liberty motor was to design a motor which was fundamentally correct in every detail, which would use but one cylinder and one set of valves. The original motors were built with eight cylinders. Before they were completed they were changed to twelve cylinders.

The twelve-cylinder Liberty motor weighs about 820 pounds and will deliver about 425 horse-power. That is a little bit better than two pounds per horse-power. There is nothing else in the world that will touch it. I rode in a machine recently that had an engine which had been on the block for 156 hours at full load. Without grinding a valve or touching anything else, we had it up in an aeroplane and were making some very remarkable records with it. So when the average life of an aeroplane is given as fifty hours, it does not necessarily mean it is worn out in that time. To keep five thousand aeroplanes on the front, it was necessary to build five thousand a month. In other words, the loss of aeroplanes was one hundred percent a month. This means that in order to keep five thousand planes on the front for a year, sixty thousand a year must be built. That does not mean that every aviator gets killed, because a machine can be broken up pretty badly without hurting anybody.

One should go to Detroit and go through the Packard, the Ford, the Cadillac and the Lincoln plants, and then go down to Indianapolis and go through the Marmon plant and see the millions upon millions of dollars' worth of specification materials and special tool equipment that has been developed to build the Liberty motor.

This cylinder is being manufactured in the most unique way imaginable. The Ford Motor Company is making the forgings for those cylinders. They are not made by boring them out. A scheme has been developed of taking a tube and closing it at the end. Now if one takes a tube and tries to close it in at the end, it cannot be closed in entirely. But instead of cutting the tube off straight at the end, it is cut on a slant and closed up so that the hole is off center, and it comes just where the valve is placed.

The complete block when it is ready to bore only weighs about thirty pounds, and only about fifty percent is taken off. The processes of grinding and valving have been developed to a high degree of efficiency. On July 4, 1917, the first pieces of the first motor were put together, and about twenty a day are being made right now. There is no trouble about running the production on up to two or three hundred a day. No motor car company ever went into business that brought through a piece of complex machinery like that any faster. There have been a lot of changes, but they were simply changes that made it possible to use machine tools

which could be had to do the work, instead of waiting to build special tools. So nobody need worry about the aviation motor program, because we are going to have more and better motors than any other country on earth.

All sorts of criticisms have been heard. It has been said the Liberty motor was not fast enough. If there is any fool thing a man can say, it is that a motor is not fast enough. A motor does not have much else to do than ride on the certain type of aeroplane it happens to be in, and it cannot ride any faster than the plane will go. The first thing to be concerned with in any aviation motor is, what is the weight factor? In the Liberty motor it is under two pounds, which is wonderful. Then, what is the fuel factor? At partially-throttled conditions, which is the way the motor is used the most, we get a fuel consumption of 0.46 pounds, and we have equalled, practically, the best that has ever been done. A great deal of this criticism is based on what it is thought a motor should do on the ground. An aeroplane motor is not designed to run on the ground, and the conditions in an aeroplane are quite different from what they are on the ground, and therefore a great many things have to be taken into consideration in the design of an aeroplane motor that need not be taken into consideration in the design of an automobile motor. The least important functioning of a motor is under ten thousand feet, because the business district in the aviation game is from ten thousand feet on up. When one thinks of eighteen or nineteen thousand feet in the air, one must also consider that there is less than one-half as much air per cubic foot than we have down on the surface. Then one can understand why there are quite a lot of different problems to conquer. A lot of people have not gotten far enough up in the air to know there is any difference in the air, up or down. When one knows that on a nice, sunshiny day, the temperature might be about sixty or seventy on the ground, while at a height of fifteen thousand feet it would be eight or nine degrees below zero, something of the difficulties of designing a motor that will adjust itself to those rapidly changing conditions can be imagined.

It is very surprising to get into an aeroplane on a nice warm day and go up and get cooled off—and one usually goes if he gets high enough. A great many of these problems are not taken into consideration at all by the average man who is doing the criticizing. All the motor can do is to ride on the aeroplane, and that aeroplane has to be designed to go higher or lower and take the motor with it. As long as there is the power factor here of weight per horse-power, it will go just as high as the plane will take it.

The important thing in designing an aeroplane is the number of pounds to be supported per square foot of plane area. If it is ten pounds per square foot, and one keeps on going up, the air keeps getting thinner and thinner, and the power of the motor gets less and less, and one will find it reaches a point where he can go no higher. Now if the plane is designed to carry four

pounds per square foot, one can go on up. That is the whole situation. With a motor like this any kind of an air craft can be designed to do anything that anybody else can do.

This motor gives its full power at about 1750 revolutions. There has been a great deal of long-drawn-out talk to the effect that the motor ought to be geared down, because the people over in Europe have found out that motors ought to be geared down. We had a meeting recently at Dayton, at which two of the members of the Council of the Society of Automotive Engineers who had just returned from Europe were present, and one of the particular things they told us about was that both the English and the French were taking out all of the geared motors and putting in direct drive motors; that there is only one geared motor on the other side and that is the "Rolls-Royce" motor. The "Rolls-Royce" motor is so geared that the speed reduction is only about 40 percent. This is accomplished by means of an epicyclic gear, which is quite a nice piece of mechanism.

It is interesting to know, however, that a geared motor is not as good as a direct-drive motor at speeds above a hundred miles an hour, and if aeroplanes are built to go better than 150 miles an hour, we are going to have to gear the propeller up, because it happens that a propeller is only a tap, tapping a hole through the air. It is just cutting a thread through the air, and it cannot cut with too coarse a pitch and get efficiency out of it. We first started out to build aeroplanes with two machine guns on them. But we found that with the additional horse-power we had on the motors we could carry four machine guns quite as well as two, and therefore we put four machine guns on them. A particular plane carrying this motor weighs about 4,400 pounds. That machine will climb ten thousand feet in seven minutes, almost two miles. That is as good as a good race horse will do right around a track, only this is going straight up, and pulling 4,400 pounds along. It has a flying speed of between 134 and 140 miles an hour.

One very interesting thing in connection with any aircraft motor is that practically all the aircraft men would have two spark plugs in the cylinders. Now the motor would pull just as many horse-power with only one spark plug as it would with two, but the exhaust valves will burn out quicker with one than with the two spark plugs, because, with the two, two fires strike at once and burn the mixture up earlier in the stroke and let the water jackets get a little more heat, while if lighted in only one place the mixture burns longer and more heat goes out through the exhaust valve. The result is that the motor lasts a lot longer than it otherwise would. This illustration is just one of a thousand that have to be taken into consideration in an aeroplane engine, with a power plant of 425 horse-power that weighs just 820 pounds.

The future of the aeroplane is going to depend somewhat on the electrical engineers. Some day we are going to have a wireless motor that will get its energy from the ground instead of having to

carry a supply of fuel and there is a big demand for such a machine right now. While a speed of 150 to 160 miles per hour is not very fast for an aeroplane the air-speed resistance is an important consideration. The increase in horse-power does not give very much increase in speed because of this limitation.

I wish to tell you a point or two about the aeroplane. A great many people have the erroneous idea that if a motor stops in an aeroplane up in the air the motor falls out. That is not so at all. The only thing you have the motor in there for is to pull the aeroplane up in the air. If any flat surface is pulled through the air, it is going to strike the air and deflect it and a reaction will be obtained. If you are pulling at the center the number of pounds it takes to pull it is called drift; the number of pounds it takes to raise it is called lift. If you consider it as a plane blade that goes ahead and shaves so many cubic feet of air per second, the reaction will cause a lift. If, instead of making it a perfectly flat surface, you modify the surface with a curve, you will not "kick" the air in the face quite so hard, and for a pound drift you can get a bigger lift. In fact, you can run it up as much as ten or fifteen times as much. Now if you will just stop and think a moment and consider the structure of an aeroplane, you will find it simple. There are only the two blades of a steam turbine flying through the air, instead of the air flying through them. There is no difference at all, for, if you hold the surface and blow the air against it at the same rate, you will get the same reaction.

The wing curves are determined largely from the maximum speed you want to get, just as the turbine blade is determined; so that for a slow or low speed machine, with a high lift, you make the curves pretty abrupt, while for a very high speed machine you make the curves with a lesser radius. There will be a vacuum right above the wings. First of all you must remember that air has weight, and if you kick it out of the road in a hurry, below the wings, the air from above cannot come in right away, and the result is that the pressure below is increased less than it is diminished above, so of course the resultant pressure is increased.

With two surfaces one placed above the other you have a biplane; with three placed one above the other it is called a tri-plane; with but one surface, it is called a mono-plane. That is just simply up to the fancy of the designer. The next thing to do is to control the machine in the air. There are three controls in the fuselage. An aeroplane supported up in the wind is a mass that can turn around any one of three axes, it can fly along horizontally, can turn around on the vertical axis, or tend to roll around the direction of motion. It is necessary to correct the latter, and it is done in an easy way. Just have the wings hinged. If you are tipping down, just turn one wing down a little and the other wing a little the other way. Now if you tip the machine so that the tail end of it is depressed, it makes the machine climb; if you raise the tail end, it

makes the machine go down. If you want to turn the machine around you just turn the rudder and it makes the machine circle.

The relationship between the lateral controls and the turning is very interesting. Most people think that in order to turn around you have to bank the machine on the turn, but you do not. The minute you turn the rudder and support the tail of the plane, it immediately begins to climb, and what you have to do is keep it from banking. An aeroplane when slipping endwise does not have very much lifting power. The side slipping is the most dangerous thing to watch out for.

The controls of an ordinary areoplane are very simple, and one control used today, which is known as the "stick control," will be described. The aviator sits on a chair with the stick control immediately in front of him. This stick control can be moved sidewise or forward or backward, depending on the direction of motion the aviator wishes. If he wants to control the laterals he moves the stick sidewise; when he wants to go down, he shoves the stick forward, and when he wants to climb, he pulls the stick back. If he wants to turn around in one direction he pushes the rudder around one side, and if he wants to turn around in the other direction, he pushes the rudder around to the other side.

One may think flying is a hard thing to do, but flying to the military aviator has to be as secondary to him as walking, because he has a couple of machine guns to shoot, which require his attention. So the art of flying has to be just as natural as the art of walking. In the ordinary battle plane, the aviator's guns are fixed on a rigid base and shoot directly through the propeller, the rate of fire of the guns being synchronized with the rate of movement of the propeller blades. It sounds as if a shot could not be fired through those blades without hitting them, but in reality it is a very simple matter. The propeller takes up only about fifteen percent of the circle. Standing behind the propeller with a rifle and trying to hit the blades, one would have just about one chance in seven of doing it.

The operator has what he calls a telescopic sight to look through, known as the "Aldis" sight. It is a right side up camera, and when looked through one thinks he is looking right at the object, but when the eye is moved back and forth one finds the object does not move at all. One is merely looking at a picture of the thing he wants to hit, and the aviator's whole stunt is to so manipulate his plane that the target he wants to hit is in the picture.

The principal business of the fellow in the back end of the plane is taking care of two Lewis guns, looking after the camera and photographic apparatus, tending the bomb-dropping sights, taking care of the maps, and various other things like that, so it is a fairly busy job.

These machines are built in all sizes and shapes. There is what is called the fighting machine, the pursuit machine, the day-bombing machine, and the night-bombing machine. The fighting machine

is a small plane, very maneuverable, and having a good climb, with a speed of about 125 miles per hour, and it can be walloped around in the air very nicely. It carries one or two guns, and this was the star machine of the Allies. The Germans countered to this in what is known as the pursuit machine. It is the same general type of machine as the Allies fighting machine, except that it makes no pretensions of being as fast a climber, but it excels in the ability to go straight down.

The main hobby, and in fact the whole tactics, of the German fighter was to get above and wait until a hostile machine is seen below, and then to simply turn the machine straight down and go after him. They have developed the highest dive factor on any front, and that is what is known as two plus. This means that the machine will dive a little better than twice its flying speed, and it is not a very difficult thing to get 220 miles an hour speed on a dive of that kind. So if one of those pursuit machines gets caught below a fighter and the pursuit machine takes a notion to leave, he just leaves. But if the fighter is below the pursuit machine and takes a notion to leave, the pursuit machine just sits on top of him. The best thing to do on a dive of that sort is to keep on diving and come out of it easy, because, if one gets nervous on a dive like that, the chances are he will lose his wings. The most effective method in a case of that kind, and the one which is worked the most, is to try to make the fellow keep on diving. Above a certain speed, instead of the air hugging down nice and tight, the control surfaces will not go over and hit the air, and when that happens the plane just keeps right on going down.

The next type of machine is the day bomber. It has to have a lot of power, speed, climb, and in fact a lot of everything. It is just a good type of aero truck that can take anything up in the air, but it has to be fast enough so that it will not get picked up while delivering the goods.

The night bomber is a great big machine of the Caproni or some other type designed to take a ton or two of explosives and a gang of men and go out snooping around in the dark, drop the explosives and return to the base.

CLOSURE.

Mr. Kettering: The discussion brought out a number of valuable points, some of which have been somewhat elaborated on in this closure. For better reference they are treated in a little different sequence from their order in the discussion.

There is only one Liberty motor. We are not building any of the single plane fighters over here at all.

The "A. B. C." motor is a very elementary type of motor. It is simply a plain cylinder with the copper fins amalgamated on. It is the plainest kind of a four-cycle motor, carbureted in the ordinary way, with a circular intake pipe going clear around the motor so there will be no trouble with the fuel proposition.

Up to the present time the two-cycle engine has not been made

as light as the four-cycle, and no way has been found to get the fuel economy down. It has never, I think, been brought below 0.70 of a pound per horse-power hour.

Steel cylinders have not been generally used for automobiles because they have been too expensive. The steel used in these cylinders is just about ordinary twenty to forty point carbon steel.

It is much better to use cast iron piston rings than any other type. Ordinary piston rings are used on the Liberty motor.

The aluminum pistons have about .020 inch clearance. The only trouble with the alumnium pistons in some cars is that either the designer or the man who sold them did not quite appreciate the problem. It is not necessary to put an aluminum piston into a motor just because it happens to be light, but putting an aluminum piston into a gas engine gets very high power out of it, because the conductivity of aluminum is so much greater than that of iron. An examination of the piston of the Liberty motor will show that it is not for lightness that the aluminum is used, for it will be found that it is quite a heavy piston. The center of the piston is cooled by running the heat units off down the side. The big thing in the aluminum is the cooling. When the designers put it in the automobile pistons they evidently forgot that ninety percent of the time the motor is running with from fifteen to twenty inches of vacuum in the intake pipe, and spark plug trouble occurred that would not have occurred had the engine been warmed up.

Efficiency is not maintained in the rarified air at the high altitudes. There is an adjustment on the carburetor, but less horsepower is needed up there, because there is not so much air, and less force is required to pull the plane through the air. If gravity would only fall off the thing would be cinched fine. One very gratifying feature, when up fifteen thousand feet in the air, is that the plane slows up as it approaches the earth, because of the increased density of the air.

Remedying the hot spot is a distribution problem. If wet gas is brought in, and it strikes the hot spot and is vaporized, then the vapor does not care whether it is turned into vapor or not. But if it is taken in, as in an atomized form, when it comes to the corners, it does not turn the corner at all. One would naturally think that the wet fuel would go to the outside, but it does not. It stays inside.

When knocking is due to high pressure of the gases, it depends altogether on where the knocking takes place whether or not the engine loses power. If it is a knocking due to premature firing, then the pressure is developed very rapidly before the piston arrives at the top center. A motor can run and have a knock without falling off one ounce in power if it is one of these destructive fuel knocks. The only thing is that the connecting-rod bearings get sore after a while.

The lubrication of the Liberty motor is entirely successful. The original type of Liberty motor was designed with what is known

as a Scupper feed. Little traps were placed out at the side of each crank shaft jaw to catch the oil and centrifugal force was used for lubricating the connecting-rod bearings. The difficulty of it was that method did not use all of the oil. On long runs there was a tendency to over-heat the portion of the oil that was used, and there was not the perfectly positive type of lubrication that is obtained by forcing the oil. The only change necessary was putting the pressure pump on the motor. We have found in the oil situation that to get an oil of the right viscosity the viscosity should be secured by a narrow cut of a lubricating oil, rather than a light oil and a heavy oil mixed together. In this country it is perfectly easy to get the narrow cut without using any castor oil. It is a narrow temperature oil.

Ignition in the Liberty motor is obtained from two high-tension distributors mounted on the cam shaft, a generator and a storage battery. The Liberty motor has its cylinders at 45 degrees instead of the usual 60 degrees. This is to prevent making the fuselage of the nose of the machine wide. The corresponding English motor is ignited with magnetos, using four magnetos for running the machine, and an extra mageto to be used in starting. The weight of the starting system of the Liberty motor is just 34 pounds, and the motor starts by simply pulling the propeller. The weight in the English motor is 135 pounds.

What we are interested in, in any ignition system, is the spark that ignites the charge; and we are not interested in anything else. If a thermometer is placed in a spark gap of one spark plug, it may show four or five times as much heat as in a spark plug of another type. If the point of ignition is measured, ten or fifteen times as much heat might be found. The thermal capacity as applied to the ignition when the spark goes across is what we are after;—the minimum amount of heat energy put across the spark gap to get ignition as long as the spark plugs are going to last.

Loss of potential through induction is a purely technical problem. When a high-tension wire goes through a metal tube supported on insulators, and the electrostatic pressure arises in the wire to strike across the spark gap, it induces a potential in the tube. If the tube gets dirty or wet, so that the potential is able to shoot some juice down across that, just that much energy is lost. If the wire is put in a fibre conduit, that conduit catches the grease and oil, but if it is put in a copper tube and grounded absolutely to the motor, the only losses possible are the $I^2R^2N^2R$ losses. Some fellow said this thing would not work, and he always proved this was wrong by laying a high-tension wire through a brass tube on the table and drawing off the spark with the finger.

When there is braid on the wire it collects the oil and grease, and that soaks through to the wire and makes a poor condenser on

the wire. We do not like a braid on the wire. The real good high-tension wire, today, is the copper, then the rubber covering, then a cotton braid, and then some more rubber over it. If there are little punctures through to the second braid they just distribute the potential out through them. I do not want a braid on the outside, but I do want a braid half way down on the inside.

Secretary's Report, January 22, 1919

Board of Direction, Western Society of Engineers, Chicago, Ill.

Gentlemen:

I herewith submit the annual report of the proceedings of the society for the year 1918.

The membership of the different grades of the society, as a whole, as of December 31, 1918, is as follows:

Honorary Members		3
Members—		
Resident	380	
Non-Resident	303	
Total		683
Associate Members—		
Resident	119	
Non-Resident	102	
Total		221
Affiliated Members—		
Resident	25	
Non-Resident	12	
Total		37
Junior Members—		
Resident	36	
Non-Resident	52	
Total		88
Student Members		62
Total		1,094

The following deaths have been reported during the year:

James Spellman, died on May 27, 1917.

Edward McKim Hagar, died on January 19, 1918.

Jesse Lowe, died on April 17, 1918.

Lieut. Kenneth F. Copeley, died on April 28, 1918.

Wm. A. Lydon, died on October 28, 1918.

Thirty-five meetings were held during the year, with speakers and subjects as follows:

Meeting No. 989, January 7, 1918—General meeting. Attendance, 45. "Unification of Local Government and City Management Plan for the City of Chicago." George C. Sikes, Chicago, Bureau of Public Efficiency.

January 14—Electrical Engineering Section jointly with Chicago Section A. I. E. E. Attendance, 65. "The Effects of War Conditions on the Cost and Quality of Electric Service." W. B. Jackson (Past President). This was the annual meeting of the electrical engineering section, at which time the officers for the year were elected.

Meeting No. 990, January 20—Hydraulic, Sanitary and Municipal Engineering Sections. Attendance, 30. "Analysis of the Traffic Count in Downtown Chicago." George C. D. Lenth. This was the annual meeting of the section and officers were elected.

Meeting No. 991, January 24—Annual dinner. Attendance, 225. "Railroad Valuation." Mr. Pierce Butler, general counsel of the western group of the President's Conference Committee on the Federal Valuation of Railroads.

Meeting No. 992, January 29—Bridge and Structural Engineering Section. Attendance, 120. "The Aeroplane and Its Use as a War Machine."

Lieut. Lee Hammond, U. S. N. This was the annual meeting of the section and the uniform rules of the section were adopted after amendment, and election of officers was also held.

Meeting No. 993, February 5—General meeting. Attendance, 72. "American Science in Aviation." Prof. John F. Hayford.

Meeting No. 994, February 12—Bridge and Structural Engineering Section. Attendance, 175. "Progress in the Application of Concrete to Barge and Ship Building." J. E. Freeman.

Meeting No. 995, February 19—General meeting. Attendance, 40. "James River and the Kanawha Canal." A. S. Baldwin. "The Ctiy of Washington as a Creation of our First President." Edgar S. Nethercut. At this meeting election of officers of mechanical engineering section was held.

Meeting No. 996, February 25—Electrical Engineering Section jointly with Chicago Section A. I. E. E. Attendance, 225. "The Resistance Type Furnace of Large Capacity for Temperature 400 degrees C. to 1200 degrees C." Thaddeus Bailey. "Arc Type Electric Furnaces." John A. Seede.

Meeting No. 997, March 4—Hydraulic, Sanitary and Municipal Engineering Section. Attendance, 60. "Snow Removal Problems." G. T. Donoghue, W. J. Galligan, Harry Richards, A. C. Schroeder and D. W. Roper.

Meeting No. 998, March 11—Bridge and Structural Engineering Section. Attendance, 50. "Principles of Design and Construction of New State Penitentiary at Lockport, Ill." Albert Moore Saxe.

Meeting No. 999, March 19—General meeting. Attendance, 180. "Meeting the Materials Situation." F. J. Llewellyn, "Steel Industry." Dr. Herman Von Shrenk, "Lumber Industry." B. F. Affleck, "Cement Industry." Frank Rhea of the U. S. Department of Commerce and Labor spoke with regard to the labor conditions in Japan, Corea, China and Manchuria. Edward Grey, Valuation Engineer of the Chesapeake & Ohio R. R., spoke with regard to the distribution of labor in the United States under existing war conditions.

Meeting No. 1000, March 25—Electrical Engineering Section jointly with Chicago Section A. I. E. E. Attendance, 125. "Some Possibilities in Electro-Chemical Industries." Dr. Chas. F. Burgess.

Meeting No. 1001, April 1—General meeting. Attendance, 45. "How Can America Meet World Competition After the War." Wm. O. Lichtner.

Meeting No. 1002, April 8—Bridge and Structural Engineering Section. Attendance, 95. "Stresses in Ships." Sydney V. James.

Meeting No. 1003, April 15—Mechanical Engineering Section. Attendance, 65. "The Storage of Bituminous Coal." Prof. H. H. Stoek.

Meeting No. 1004, April 23—Electrical and Mechanical Engineering Sections with Chicago Section A. I. E. E. and Chicago Section A. S. M. E. "The Automobile Power Plant." C. F. Kittering, President, S. A. E.

Meeting No. 1005, May 6—General meeting. Attendance, 53. "Unified Transportation System for the City of Chicago." Geo. Weston.

Meeting No. 1006, May 13—Bridge and Structural Engineering Section. Attendance, 81. "The Pneumatic Method of Concreting." H. B. Kirkland.

Meeting No. 1007, May 20. Hydraulic, Sanitary and Municipal Engineering Section. Attendance, 40. "Thoroughfares." O. C. Simonds.

Meeting No. 1008, May 27—Electrical Engineering Section jointly with Chicago Section A. I. E. E. and Chicago Section I. E. S. Attendance, 61. "Regulation of Street Series Lamps in Practice." F. A. Vaughn. At this meeting the uniform rules of the section were adopted. This being the regular annual meeting of the Chicago Section A. I. E. E., officers for the year were elected.

Meeting No. 1009, June 3—General meeting. Attendance, 50. "The Work of the Fuel Administration." Prof. H. H. Stoek, Chairman of Coal Conservation Committee; David Moffett Mayer, Consulting Engineer for the

United States Fuel Administration; Dr. F. C. Honnold, District Representative, United States Fuel Administration; C. E. Naylor, Consulting Engineer, Chicago; W. D. Langtry, Consulting Engineer, Chicago; Osborn Monnett, Consulting Engineer, Chicago.

Meeting No. 1010, June 10—Bridge and Structural Engineering Section. Attendance, 67. "Concrete Caissons Sunk by Open Dredging Method." L. W. Skov.

Meeting No. 1011, June 17—Electrical and Mechanical Engineering Section with Chicago Section A. I. E. E. and Chicago Section A. S. M. E. Attendance, 130. "Advantages of High Pressure and Superheat as Affecting Steam Plant Efficiency." Eskil Berg, Schenectady, N. Y. "Condensers." D. W. R. Morgan, East Pittsburgh, Pa.

Meeting No. 1012, June 27—Special meeting. Attendance, 75. Meeting held at Engineering Hall, Northwestern University, jointly with the Society for the Promotion of Engineering Education. "Technical Education and the War." A. S. Baldwin, W. L. Abbott, F. F. Gernandt, Dr. C. R. Mann, Henry G. Cox, John R. Bibbins.

Meeting No. 1013, September 9—Bridge and Structural Engineering Section. Attendance, 53. "Erection of the Union Pacific Railroad Bridge over the Missouri River at Omaha." K. L. Strickland.

Meeting No. 1014, September 23—Hydraulic, Sanitary and Municipal Engineering Section. Attendance, 30. "Good Roads in Illinois." William G. Edens, Chicago.

Meeting No. 1015, October 7—General meeting. Attendance, 38. "The First Nine Months of Government Operation of the Railways." E. T. Howson.

Meeting No. 1016, October 14—Bridge and Structural Section. Attendance, 52. "Compensation of Engineers." W. H. Finley.

Meeting No. 1017, November 11—Bridge and Structural Engineering Section. Attendance, 15. "Handling and Storage of Bulk Cement." Wallace R. Harris.

Meeting No. 1018, November 12—Electrical and Mechanical Engineering Section and Chicago Section A. S. M. E. and A. I. E. E. and I. E. S. Attendance, 75. "Industrial Lighting and the War." Prof. C. E. Clewell of the University of Pennsylvania. The annual election of the Mechanical Section was held and also nominations for officers of Electrical Engineering Section.

Meeting No. 1019, November 18—Ladies' night. Attendance, 240. "Destruction and Reconstruction." S. J. Duncan-Clark. Music was furnished by the Universal Glee Club and Cora Libberton.

Meeting No. 1020, November 25—General meeting jointly with members Societies of War Committee. Attendance, 200. "Lighting Curtailment." Preston S. Millar.

Meeting No. 1021, December 9—Bridge and Structural Engineering Section. Attendance, 150. "Design and Erection of the Metropolis Bridge." Ralph Mojeski. At this meeting election of officers of the Section was held.

Meeting No. 1022, December 16. Hydraulic, Sanitary and Municipal Engineering Sections. Attendance, 26. "The Effect of Metering on Water Consumption." Hubert P. T. Matte. At this meeting the uniform rules of the section were adopted and election of officers for the ensuing year was held.

Meeting No. 1023, December 30—Electrical Engineering jointly with Chicago Section A. I. E. E. Attendance, 180. "Electric Welding in Ship Building." Comfort A. Adams, President, American Institute of Electrical Engineers.

EDGAR S. NETHERCUT, *Secretary*.

January, 1919

Report of Judges of Election, Western Society of Engineers, January 17, 1919

The undersigned Judges of Election, having canvassed the ballots cast for officers of the Western Society of Engineers for the year 1919, have the honor to report as follows:

Total number of votes cast	301
Total number of ballots rejected as irregular	22
Total number rejected as not qualified to vote on account of non-payment of dues	1
Total number of ballots counted	278
For President:	
A. S. Baldwin	274
For First Vice-President:	
K. B. Miller	272
For Second Vice-President:	
Wm. M. Kinney	272
For Third Vice-President:	
J. L. Hecht	273
For Treasurer:	
C. R. Dart	274
For Trustee for three years:	
E. T. Howson	274
For Members of Washington Award Commission fgor three years:	
E. H. Lee	272
F. E. Turneaure	268

Respectfully submitted,

W. G. Potter,
Geo. W. Hand,
J. H. Heuser,

Judges of Election.

Approved by Board January 17, 1919.
Edgar S. Nethercut, *Secretary.*

Proceedings of the Annual Meeting and Dinner, January 22, 1919

The annual meeting and dinner were held at the Hotel Sherman, Chicago, and were attended by 465 members and guests. After dinner the meeting was called to order by Mr. C. B. Burdick, President.

Mr. Burdick presented the report of the Chanute Medal committee signed by Messrs. R. F. Schuchardt, chairman, W. W. DeBerard, W. S. Lacher and T. L. Condron, awarding the Chanute Medal to Mr. Burt H. Peck for his paper on electrical engineering. Mr. Peck was thereupon awarded the Chanute Medal for the year 1917.

The president also announced the Washington Award, founded by Mr. John W. Alvord, past president, W. S. E., for the greatest service to humanity by an engineer to Mr. Herbert C. Hoover, National Food Administrator.

The president thereupon presented his address as retiring president, which will be found elsewhere in this issue. At the conclusion of this address

the president announced the result of the annual election of officers and the members of the board of direction for the year 1919, as follows:

President	A. Stewart Baldwin
First Vice-President	K. B. Miller
Second Vice-president	Wm. M. Kinney
Third Vice-president	J. L. Hecht
Treasurer	Carlton R. Dart
Trustee, 1 year	O. F. Dalstrom
Trustee, 2 years	W. W. DeBerard
Trustee, 3 years	E. T. Howson
Past presidents	Charles B. Burdick H. J. Burt B. E. Grant

Section Chairmen—

Electrical Engineering Section, J. R. Cravath.
Bridge and Structural Engineering Section, G. A. Haggander.
Hydraulic, Sanitary and Municipal Engineering Section, F. J. Postel.
Gas Engineering Section, H. H. Clark.

President elect, A. S. Baldwin, was then introduced and presented his inaugural address, which also appears elsewhere in this issue, at the close of which Dr. E. H. Lewis, dean of the Faculty of Lewis Institute, was presented as toastmaster.

Dr. Lewis: Mr. President and Gentlemen: The first speaker of the evening doesn't like to make speeches. He is a man of deeds and not of words, a highly successful engineer, a great organizer, and therefore he doesn't care very much about talking shop. You may have noticed that the more successful an engineer is, the less he talks shop. But I don't know but what he has a good model for this. God Almighty himself is somewhat silent about his most intimate mechanical secrets.

I remember the last time I was in the insane asylum, I was introduced to a very venerable old gentleman, and I said, "I didn't quite catch the name." He said, "Young man, my name is God Almighty." "Well," I said, "this is a great honor; I have long desired with trembling for this honor, because there are certain questions I would like to ask you. For instance, I have always wanted to ask you what was the original origin of evil." He looked at me solemnly for a minute and he said, "Young man, I never talk shop."

Now our first speaker this evening is a great organizer, and always was. He is a man whose native state is proud of him. You know seven cities claimed the honor of Homer's birth. And they say of Mr. George Ade that seven cities disclaimed the honor of his birth, but both West Virginia and Pennsylvania claim the honor of having produced this man, because he was born in West Virginia and went from Pennsylvania to the military academy. He took all the steps there are; he made his way up slowly. He was an engineer first, last and all the time. He wasn't like a French professor that I knew of who received an appointment in the college. They sent word to the agent who provided him that this man must be a member of a certain church, that he must not smoke cigarettes; and the next qualification was that he should know as much French as is consistent with the other two.

This man has always been an engineer, an army engineer. Now in the late unpleasantness perhaps you don't happen to know that your new president was born in Winchester, W. Va. Well, that is where he came from, gentlemen. And the first speaker was reared in Pennsylvania and West Virginia and he worked his way up. When the war broke out he was an engineer of maintenance on the Panama Canal, and I don't suppose he knew anything about the difficulties of army engineering as they were in the days of Sheridan and Winchester,—but we had some engineers even then. I have been told, in such a way as to believe it, that in that late unpleasantness—thank God it is all over now—one ordinary regiment, or rather one ordinary division of infantry—not engineers, just plain ordinary infantrymen—repaired one hundred and two lines of railway and built one hundred and ten bridges, forging their own tools as they went along, in forty days.

Since then we have come a long distance under the leadership of such men as the speaker of this evening. When the war broke out he was just engaged in maintenance work in Colon. He went to France. The Fourth division took his regiment and went to work making the second line of defense directly back of Chateau Thierry. He was soon elevated to the rank of general and made chief engineer of the First Army. I looked at a list of thirty of his colonels today and very carefully sorted them out from the last edition of the Daily News Almanac and thought I was going to show some knowledge of the situation here tonight, but the general informs me they were all at the front and his men were a different bunch altogether. He was with the First Army all the time. He was so successful there that in October he was called to organize the engineer office for the Third Army. That business wasn't done until the armistice was signed, and then he was sent back to this country to continue the good work as deputy chief engineer of the American engineering forces, to be in charge of the biggest engineering camp in the world at Fort Humphreys. But whatever he says about engineers, you and I have faith in the American engineer in France.

The other day I was talking to a manufacturer of spiral pipe. He was praising to me the wonderful mathematical accuracy with which some Norwegian engineer had figured out that pipe, and made the statement that it couldn't be duplicated anywhere. But, gentlemen, you and I all know that the engineer forces of the American Army were second to none in organization, in initiative, in resources, in perseverance, and in patriotism. You don't have to ask him how he did it. Great engineering feats were done in antiquity. There was Pharaoh, for instance. He built the pyramids, and they say that is a wonderful engineering feat. Now I don't know just exactly how he did it, but I suppose the old man had them all hypnotized. But the general here didn't have them all hypnotized in France; he didn't need to. I imagine the secret was American initiative, American co-operation and American enthusiasm.

Now, gentlemen, I have the very great honor of introducing to you General J. J. Morrow.

(General Morrow's address appears on page 7.)

Toastmaster: Gentlemen, our next speaker is a man who has been associated with the higher life of Chicago for a quarter of a century and more. When you stop to think what that means it means a good deal. Chicago has had nineteen governments and fifty-seven kinds of public characters and a mayor and school board most of the time, and this gentleman, a reverend gentleman, has been in it all. He began life as a Universalist. That is the most imaginative denomination in the world. It holds as one of its principles that good will be the final goal of ill, and it takes a good deal of imagination for some of us to imagine the Hohenzollern family submitting itself to such a form of purgation as would render it good in the eyes of God Almighty.

He has had his hand in every good work. He has looked out for the homeless children. He has taught the children of Chicago to save money. He held down a chair in the school board for five years. He has learned to be philosophical. No matter what happens in the high life of Chicago he has learned to be philosophical. He has traveled all over the world and has photographed many beautiful sights. He has seen almost everything, but he loves America first. He has been to France and has brought back some pictures of the present condition on the Western Front which he is going to throw on the screen for your information and benefit this evening, and I wish you now the pleasure of listening to Dr. Rufus Austin White.

Dr. White's address was descriptive of his trip through the war zone, which was illustrated by numerous lantern slides. This address was full of inspiration and was received with applause.

Chairman: Just one moment for a word of thanks to these gentlemen who have entertained us so delightfully tonight, in which I am sure all of you will join me and we will stand adjourned.

EDGAR S. NETHERCUT, *Secretary.*

Proceedings of the Society

Meeting No. 1024, January 6, 1919.

This was a general meeting of the Society to which ladies were invited. There were present 85 members and guests. Mr. C. B. Burdick, president, presided. Mr. D. L. Derron, Works Manager, Winslow Bros. Company, of Chicago, presented a series of moving pictures and slides showing the complete process of manufacture and inspection of 155 millimeter shells for the United States government. Mr. Derron explained the particular features of the work as the slides and pictures were presented.

Meeting No. 1025 January 8, 1919.

This was the initial meeting of the Gas Engineering section, and was attended by 50 members and guests of the Society. Mr. H. H. Clark, chairman of the section, presided. H. P. Boardman presented a statement of the organization and plan of the section. Mr. W. S. Parr, Professor of Applied Chemistry of the University of Illinois, presented a paper on the "Present and Prospective Status of the Gas Industry." This paper described a series of laboratory experiments carried on at the University of Illinois during the last ten years, developing the possibility of carbonization of Illinois coal. The laboratory experiments described, indicated an enlarged opportunity for the economical use of Illinois coal and the recovery of important products such as gas, tar, oils and coke, which have a considerable commercial value.

Meeting No. 1026, January 13, 1919.

This was a meeting of the Bridge and Structural Engineering Section. There were present 64 members and guests. Mr. G. A. Haggander, chairman of the section, presided. Mr. E. L. Shaw, Chief Engineer of The La Salle Engineering Company, of Chicago, presented a paper on "The Detailing of Fabricated Ships." Mr. Shaw's paper was illustrated with lantern slides showing the designs and details of structural and machine parts of the ship so that these parts may be constructed independently at convenient locations and assembled and erected at the ship yard.

Annual Meeting of the Society January 22, 1919.

This was the Forty-ninth Annual Meeting of the Society, and was attended by 465 members and guests. Mr. C. B. Burdick, retiring president, presided. Music was furnished by Kammerer's orchestra and the Universal glee club during the dinner. The Committee on Music provided songs for ensamble singing. Mr. Burdick announced the Chanute Medal award to Mr. Bert H. Peck, also the award of the Washington Award to Mr. Herbert Clark Hoover. The address of the retiring president entitled "The Technical Society," was presented by Mr. Burdick. At the close of this address the report of the annual election was presented. Mr. A. S. Baldwin, president elect, gave his inaugural address. Dr. E. H. Lewis, toastmaster, introduced Brig.-General J. J. Morrow, Chief of Engineers, First Army, A. E. F., who described the extent of the construction work done by the army in France, which was illustrated by slides. Dr. R. A. White of Chicago gave an illustrated lecture of his observations on the Western front.

Meeting No. 1028, January 27, 1919.

This was a joint meeting of the Electrical and Mechanical Sections, W.S.E., and the Chicago Sections, A. I. E. E. and A. S. M. E. There were present 134 members and guests. Mr. F. J. Postel, chairman of the Mechanical Section, presided. The paper of the evening on the subject, "The American Beet Sugar Industry," was presented by Mr. Martin J. Kermer, General Manager and Chief Engineer, Cannon-Swenson Co., of Chicago. This was illustrated by lantern slides. Mr. H. McCormick, Professor of Applied Chemistry, Armour Institute, presented additional information and discussed the paper.

Notice—Society Badges

THE Officers of the Society have succeeded in making a more advantageous arrangement for the manufacture of our Society badges than we have heretofore had, and the Society is now able to furnish them to the membership at the following prices:

Gold badge, with blue enamel, for Members and Associate Members . . $3.00

Silver badge, with green enamel, for Junior Members and Affiliated Members $2.00

SHOW YOUR LOYALTY BY WEARING THE BADGE

JOURNAL OF THE
WESTERN SOCIETY *of* ENGINEERS

VOLUME XXIV FEBRUARY, 1919 NUMBER 2

The Metropolis Bridge Over the Ohio River at Metropolis, Ill.

By RALPH MODJESKI, M. W. S. E.,
Consulting Civil Engineer, Chicago, Ill.

Presented December 9, 1918.

CONSIDERABLE information about the Metropolis Bridge has been published in the technical papers from time to time and some of the details have been shown and described. Further details are shown on the attached plates. The writer will therefore avoid describing the bridge in detail, but will confine himself to discussing the general problems of the design and construction; treating with only such of the details as may be either of special interest or which may be required in the dicussion.

It seems quite desirable to devote a few lines to the general history of the engineering organization. The bridge was built by the Paducah and Illinois Railroad Company incorporated jointly by the Chicago, Burlington and Quincy Railroad Company and the Nashville, Chattanooga and St. Louis Railway Company, the two roads becoming joint builders and owners of the Paducah and Illinois Railroad Company. Mr. C. H. Cartlidge, Bridge Engineer of the Chicago, Burlington and Quincy Railroad Company, was made Chief Engineer, and Mr. C. R. Fickes, Resident Engineer in charge.

In May, 1910, the writer was appointed Consulting Engineer, and from that time until June, 1916, Mr. Cartlidge, in co-operation with the writer, developed the plans for the structure and directed the work. On June 14th, 1916, Mr. Cartlidge died after a most sudden and brief illness. His death was an irreparable loss to the profession as well as to his friends who all admired his great ability as an engineer and his lovable personality.

Shortly thereafter, the writer was placed in full charge of the work and carried it to completion. In May, 1917, Mr. Fickes resigned, and Mr. M. B. Case was appointed Resident Engineer in his place, and continued in that capacity until completion.

Preliminary surveys were made at different times between 1906

and 1911, and the final location was approved in 1912. This location included a bridge at Metropolis and about 13 miles of new

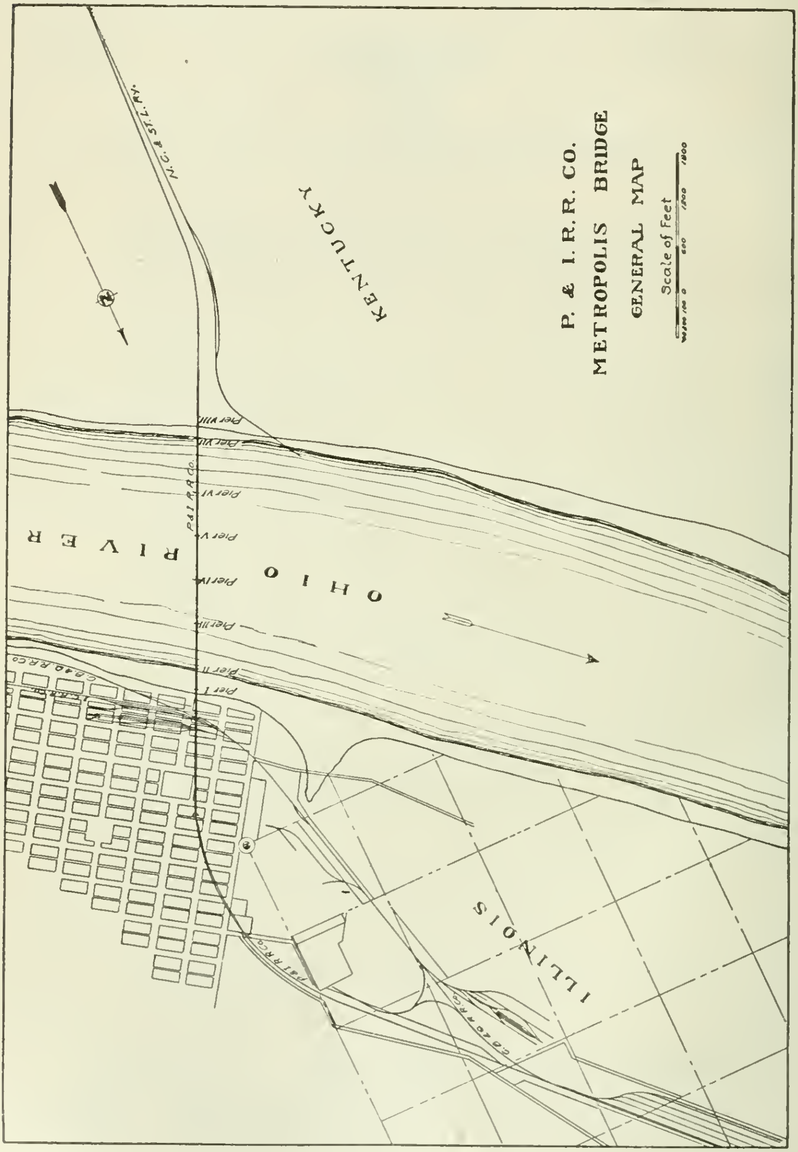

Fig. 1

line from the C. B. & Q. terminal at Metropolis to the N. C. & St. L. Railway connection at Paducah, Kentucky.

The bridge crosses the Ohio River at the town of Metropolis, about 12 miles below Paducah, Kentucky. Its direction is practically North and South.

The main bridge, beginning at the north, or Metropolis, end, consists of one 300′ 0″ through span, four 551′ 3″ through spans, one 720′ 0″ through span, and one 246′ 0″ deck span.

The length of the 720′ span was determined by the requirements of the United States Government for a 700′ clear span next to the Kentucky shore. The Government also required a clearance of 53′ above high water of 1887, or above elevation 336.71, United States Government gauge. At each end of the main bridge is a viaduct, consisting of towers and deck plate girders with a reinforced concrete slab floor, the viaduct on the south end being 604′ 9″ long, and on the north end, 1593′ 2″ long. The total length of the main bridge is 3502′ 7″ and of the entire bridge, including steel approaches, 5700′ 6″. In order to reach the required vertical clearance at the 720′ channel span, it was necessary to build the bridge on either side of that span on a 0.3% grade, ascending from shore towards the channel span. The bridge was designed for double track, but for the present is being operated as a single track structure. For economical reasons, two lines of approach girders, which are not necessary for single track operation, but will be necessary for double track, have been left out for the present. The two lines of girders which now carry the single track have been placed on the center line, and when necessary will be shifted to one side, to make room for the girders of the second track. In the truss spans, the two middle stringers are now being used; all four lines of stringers, however, have been placed in the floor, in order to have two tracks available for erection of trusses.

After the location had been decided on, the next problem was to determine the length and number of spans in the main bridge. The length of the channel span near the Kentucky shore, as said before, having been determined by the Government requirements, the problem was therefore limited to the portion of the bridge outside of that span. Several designs were considered, as to lengths of spans, ranging from 463′ to 594′ center to center piers. Estimates were made of the total cost of these including foundations and piers, and the design with four 551′ 3″ spans was adopted, as indicating the most economical arrangement. In this connection, a cantilever design was also considered, but, although showing an appreciable saving over the simple span design, the saving was not deemed sufficient to offset the advantages offered by the latter. These advantages are, a greater rigidity, and the elimination of a large percentage of members subject to reversal of stresses. A recognized advantage of the cantilever type, apart from the economy of material, lies in the greater safety of erection where danger

from flood exists. This advantage was of less importance in this bridge because of the position of the channel span and because of

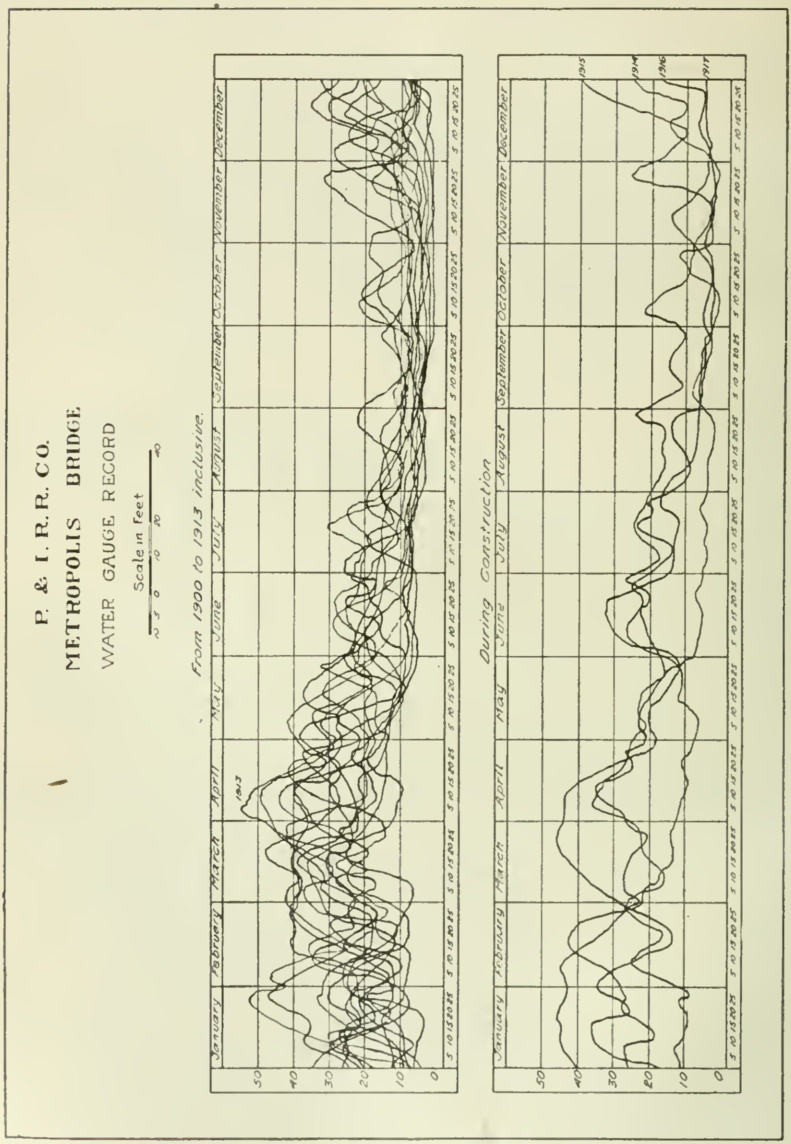

Fig. 3

the fact that it was built over a marked depression of the river bed. This depression or pool is the deepest place in the channel

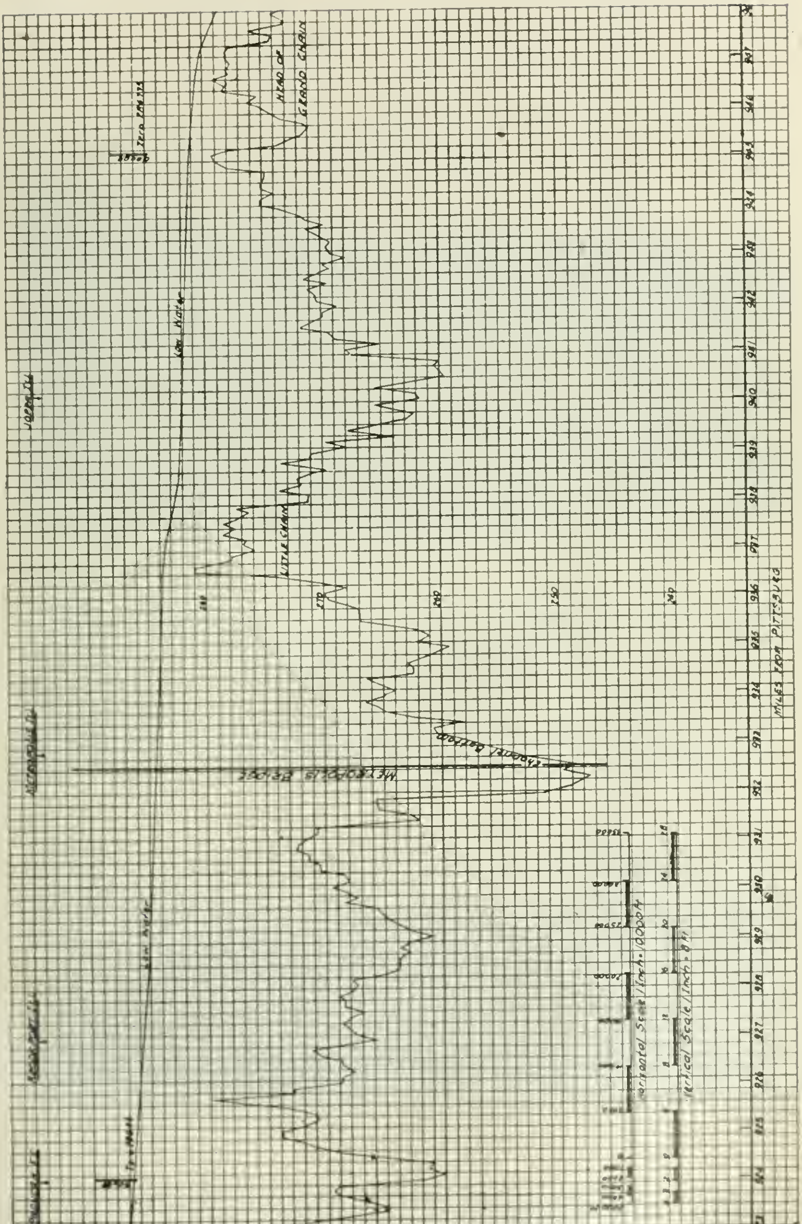

Fig. 4. Profile of Channel

between Paducah and Cairo (See Fig. 4), and would therefore not be likely to scour. In fact, no scouring was observed at the site during the eight years preceding construction. The hydrograph, Fig. 3, shows that a moderate stage of water could be expected

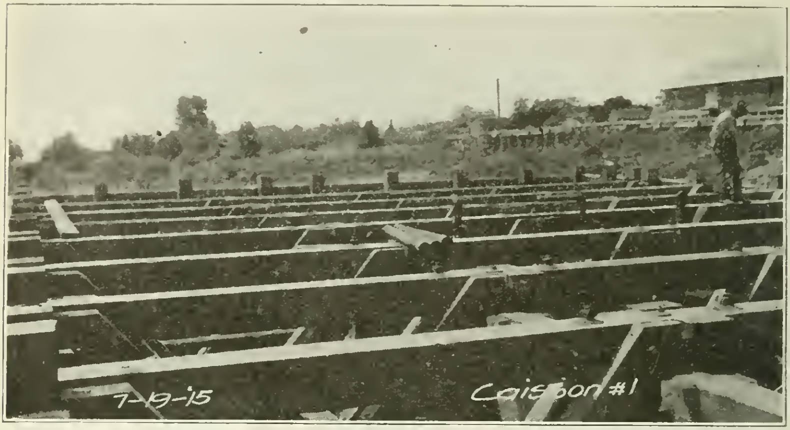

Fig. 9. Trusses in Caisson No. 1

during four months each year, and it was estimated that the channel span could be erected during that period of time.

The next problem was to determine the form and proportions of the trusses and the system of trussing. With this end in view,

Fig. 10. Pontoon.

comparative estimates were made on different depths of trusses and different panel lengths. This resulted in a decrease of the originally planned height of the 720′ span, from 120′ to 110′, and in the increase of panel length from 30′ to 36′. These comparisons

were made on the assumption that a subdivided Pratt system of trussing would be used. A "K" system of trussing was then investigated for a 720′ span, but it was found impracticable, or rather inadvisable and uneconomical. The spacing between centers of trusses was fixed at 37′; a spacing of 40′ was originally contemplated. These dimensions determined, the final design of the substructure of the main bridge was taken up.

The substructure consists of eight piers, numbered from north to south. The foundation of Pier VIII was built by open cofferdam

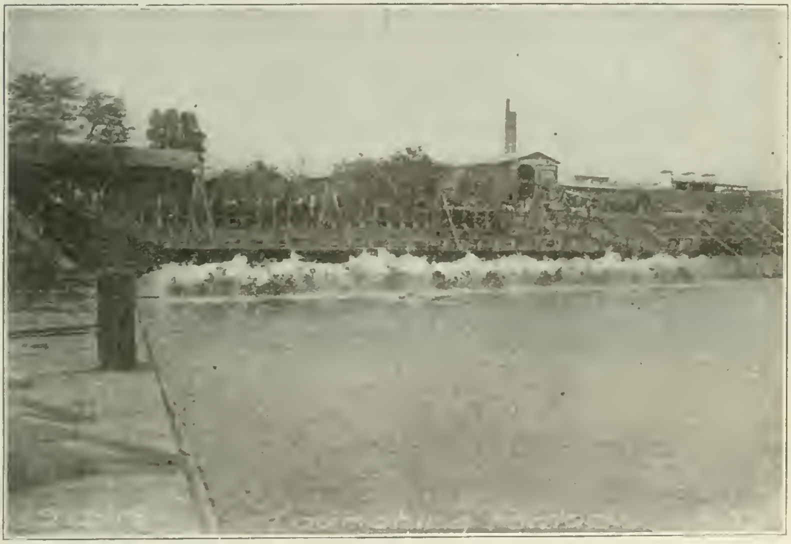

Fig. 11. Launching Pontoon

method; the other seven piers were founded by the compressed air process.

A complete series of soundings, taken on the bridge line, disclosed the material in the river bed to consist of layers and pockets of fine and coarse sand, gravel, clay of different degrees of hardness, and gumbo. Rock was encountered at a depth of 240′ below low water, or approximately at elevation 44. Bedrock, therefore, could not be reached by any ordinary method of foundation, consequently it was decided to stop the foundations in fine white quartz sand, which the borings indicated to be at a depth of about 70′ below low water, extending to rock.

As is commonly the case with soundings and wash borings, the information obtained was not uniformly correct. In the case of this bridge, some surprises were reserved for the engineers, when the caisson chamber reached the elevation planned as final.

For instance, the caisson of Pier II was sunk 23.23′ deeper than the plans called for, because of presence of clay in the sand at the

Fig. 12. Cutting Edge of Caisson

planned elevation. Pier III was sunk 18.23′ deeper for the same reason. Pier IV was sunk 15.06′ deeper for the same reason. In

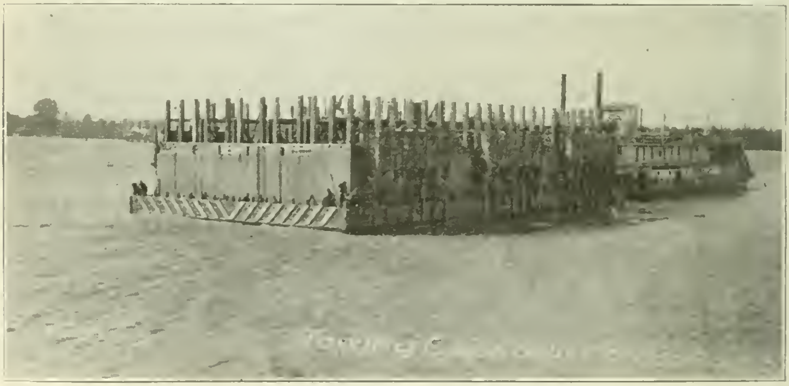

Fig. 13. Towing Caisson No. 6 in Pontoon

this pier, it resulted in a head of water of 113.2′ during sinking, with an air pressure of 51.5 lbs. in the working chamber. Pier

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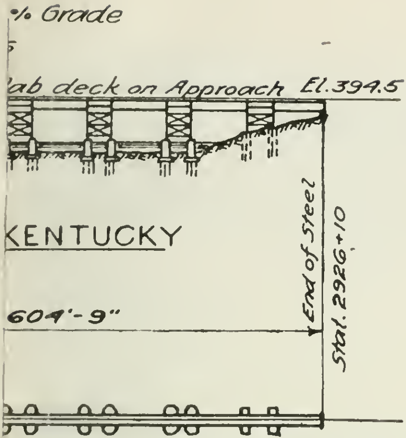

TE VII

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Fig. 2

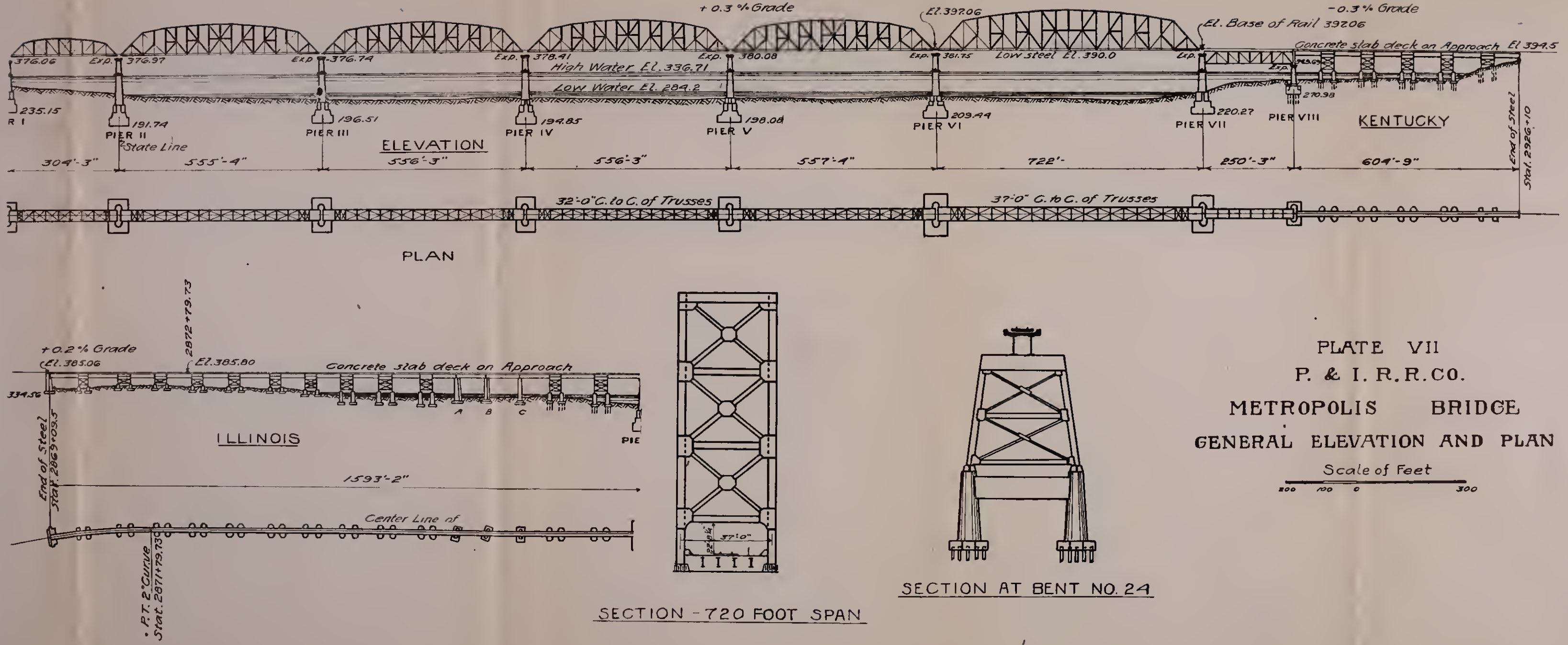


PLATE VII
P. & I. R.R. CO.
METROPOLIS BRIDGE
GENERAL ELEVATION AND PLAN

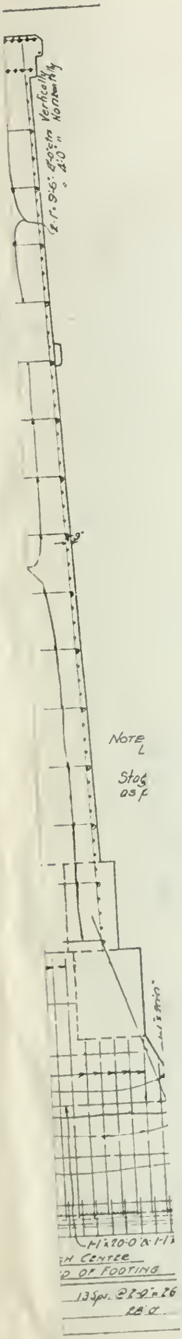
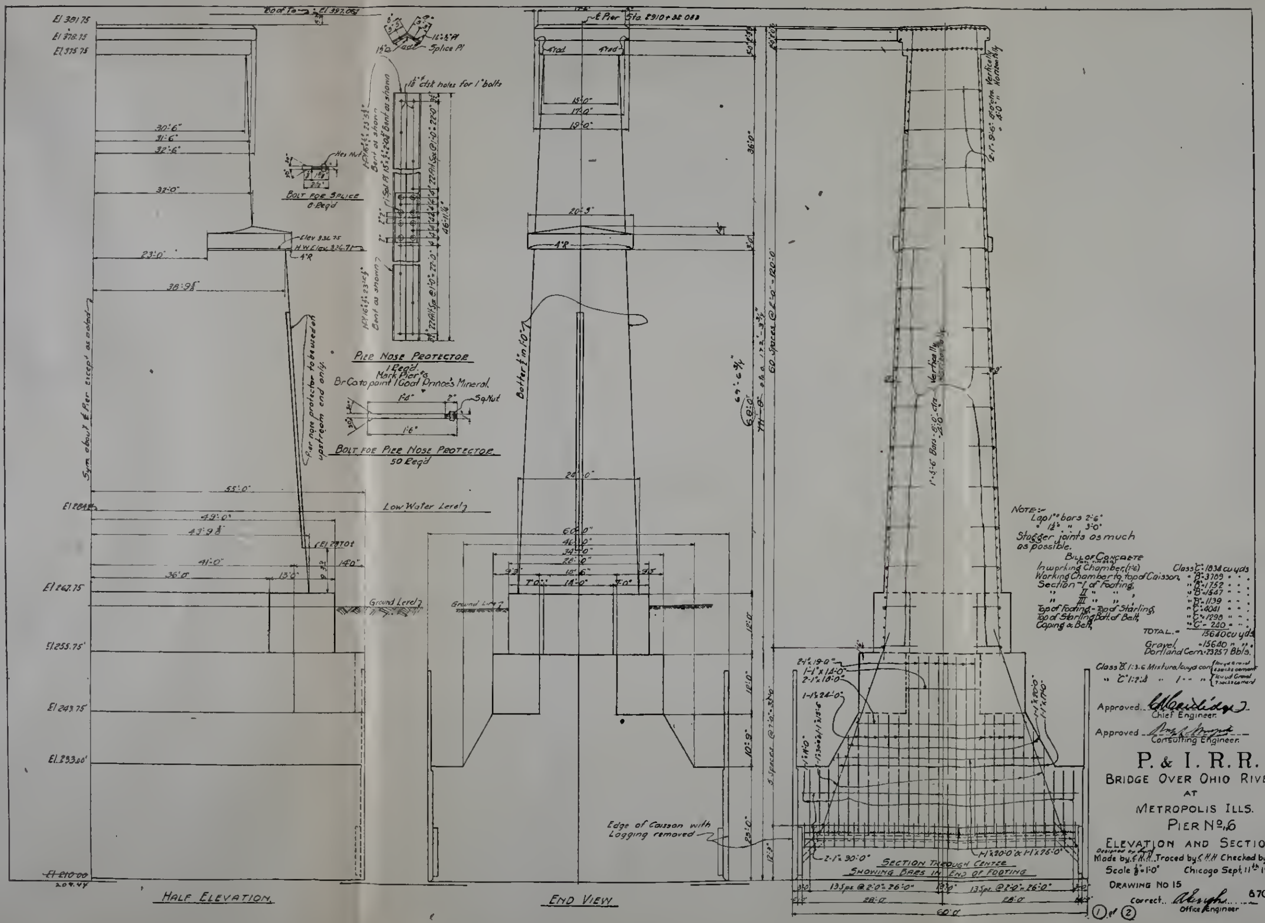


Fig. 5. Pier VI


HALF ELEVATION.
END VIEW
SECTION THROUGH CENTRE
SHOWING BARS IN END OF FOOTING
PIER NOSE PROTECTOR
BOLT FOR PIER NOSE PROTECTOR
50 Reqd
BOLT FOR SPLICE
Low Water Level
Ground Level
Edge of Caisson with Logging removed
NOTE:-
Stagger joints as much as possible.
BILL OF CONCRETE
Approved Chief Engineer.
Approved Consulting Engineer.
P. & I. R.R.
BRIDGE OVER OHIO RIVER
AT
METROPOLIS ILLS.
PIER No. 6
ELEVATION AND SECTION.
Scale 1/8"=1'-0"
Chicago Sept. 11th 1914
DRAWING NO 15
Office Engineer
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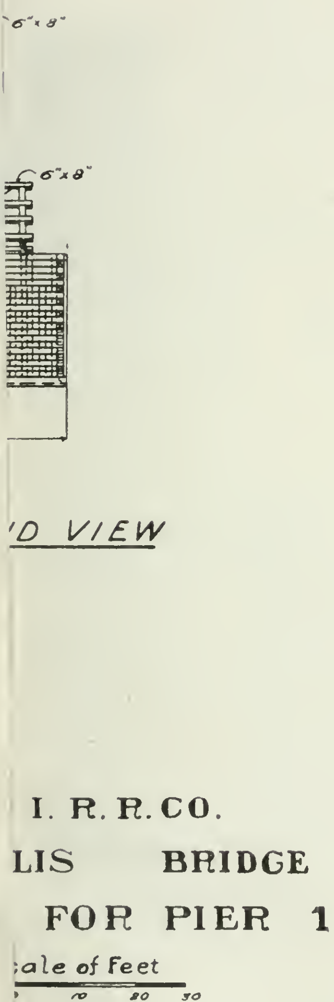

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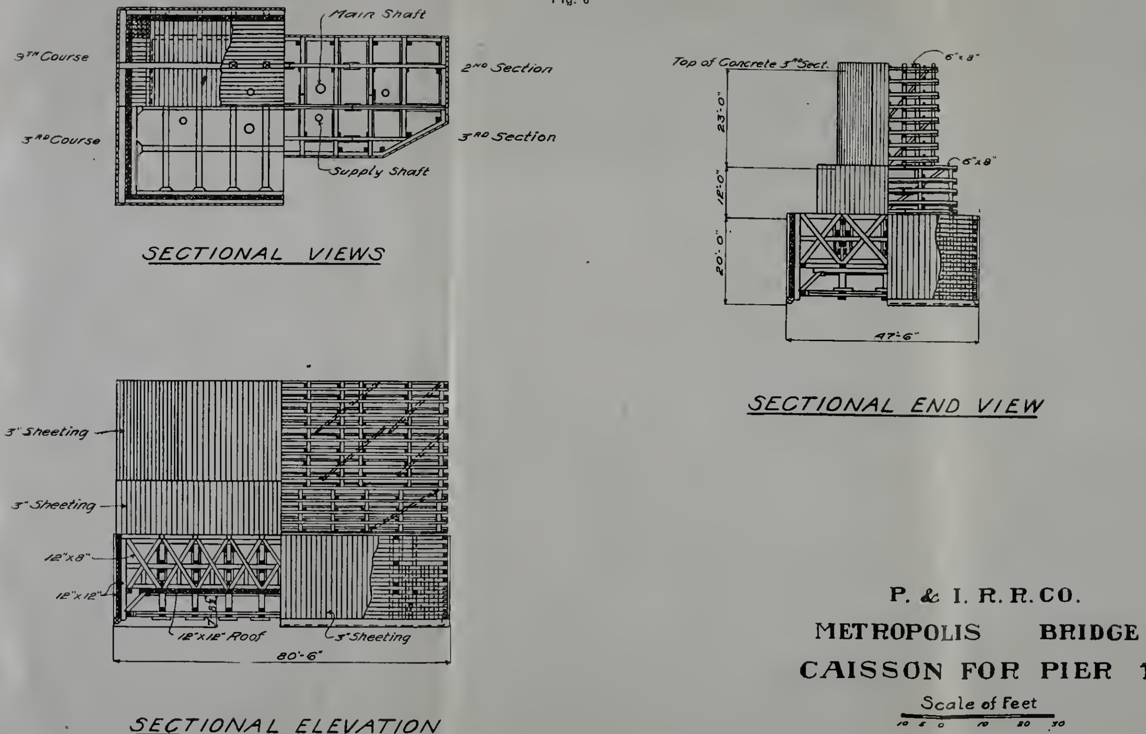
Fig. 6



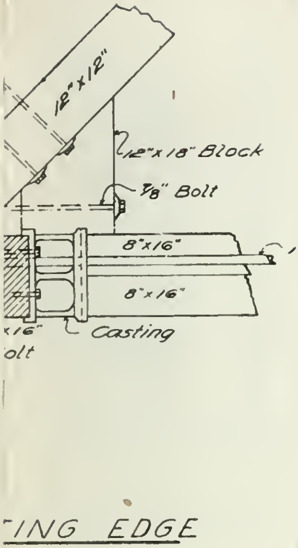


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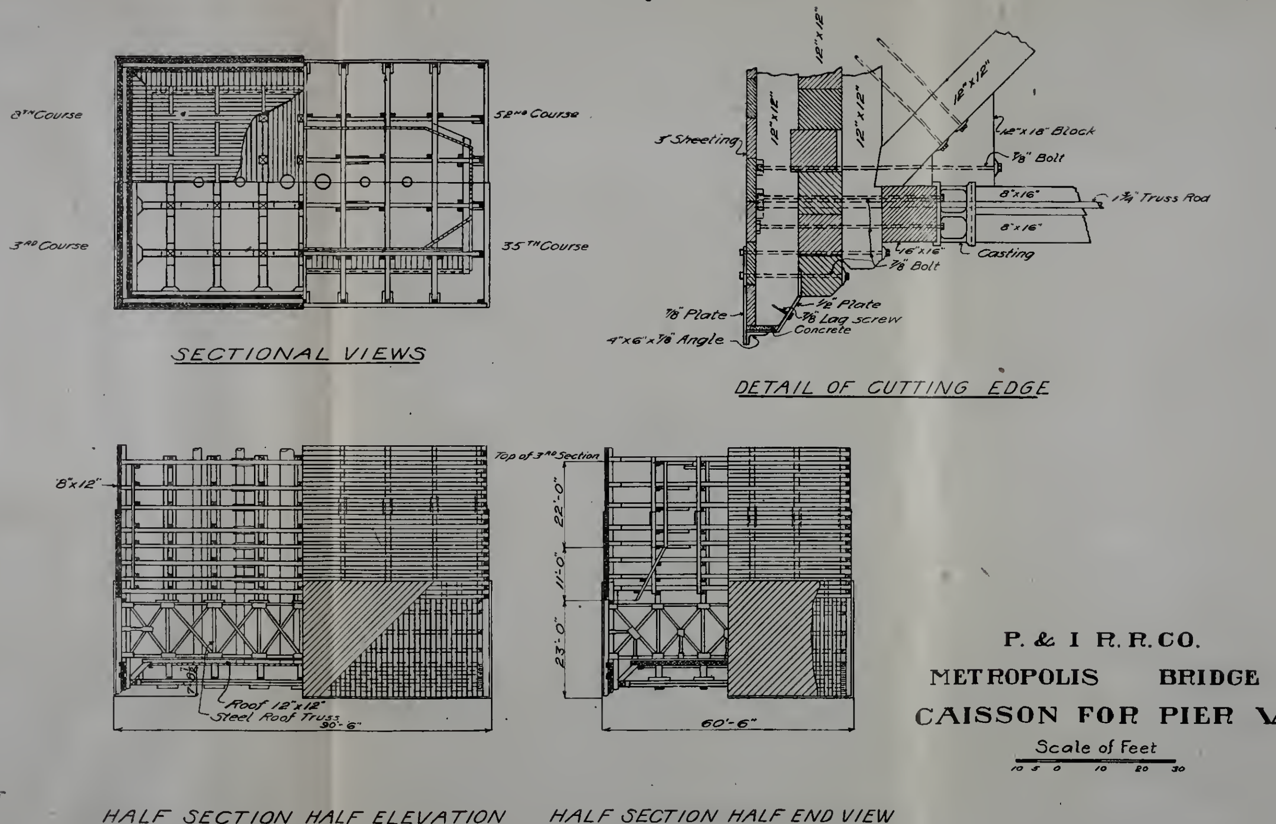
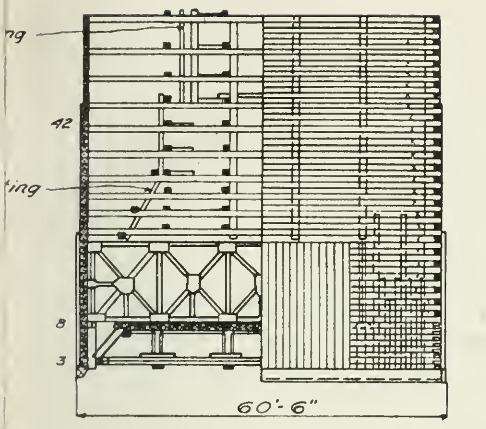
Fig. 7



P. & I R. R. CO.
METROPOLIS BRIDGE
CAISSON FOR PIER V



HALF SECTION HALF END V

P. & I. R. R. CO.

TROPOLIS BRIDGE

ISSON FOR PIER VI

Scale of Feet

10 5 0 10 20 30

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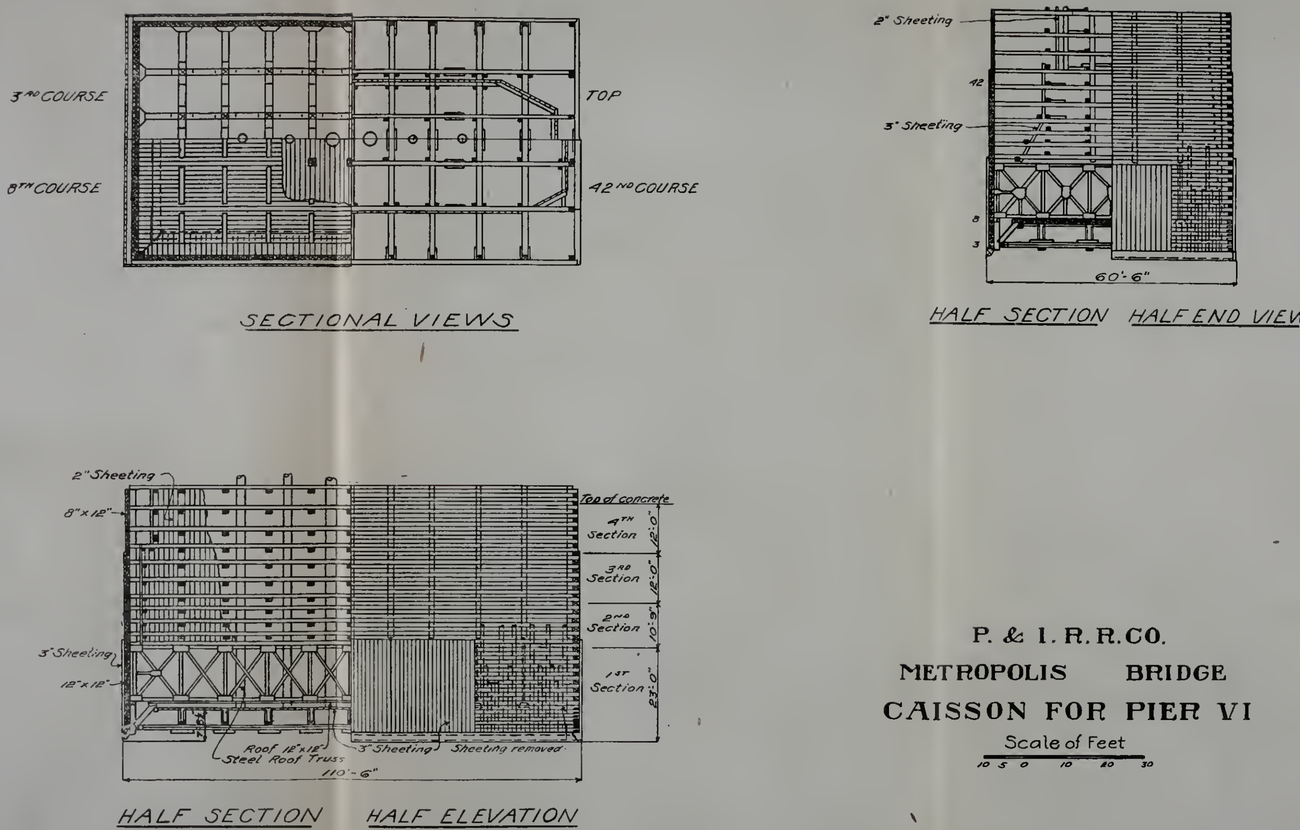
Fig. 8



V was sunk 12′ deeper than planned, due to clay in the sand at the planned elevation.

Because of the rather uncertain character of the materials as shown by the borings, it was necessary to construct caissons of large horizontal dimensions. The largest caisson in this structure was built for Pier VI. The cutting edge is 60′ 6″ by 110′ 6″. The largest caissons in the new Memphis Bridge (those of Piers II and III,) are only 42′ by 90.′ The character of the foundation materials in the Memphis Bridge was well known because of the

Fig. 14. Top of Caisson No. 6 Showing Steel Trusses

experience gathered in building the old bridge, which is only two hundred feet away. These materials consisted chiefly of hard clay. In Metropolis, the pressures on the foundations in the main piers do not exceed 8.29 tons per sq. ft. (Pier IV), of which 5.39 tons is direct load, and 2.90 tons the vertical component of traction and wind on the edge of the caisson. The greatest direct load in Memphis is 5.1 tons per sq. ft. This pressure was considered safe in the hard clay at Memphis, and is quite conservative where the material is sand as in Metropolis. Tests of the resistance of foundation soil were made in each caisson just before sealing the working chamber, and the bearing value was shown to be not less than 21 tons per sq. ft. before yielding. Pressures on the foundations in various river piers are shown on Figures 18 to 24 inclusive.

Because of the necessity to build caissons of unusual dimensions, and in order to give them additional stiffness and strength to resist

bending vertically, stiffening trusses were built in above the roof chamber. (See Figures 6, 7, and 8.) These trusses were of steel in Piers III, IV, V, VI and VII, and of wood in Piers I and II. They also supported the 12"x12" roof timbers of the working chamber, and when concreted in, made a reinforced slab of great strength. This arrangement made it possible to use only one layer of 12"x12" timber for the roof. In other respects, the caissons were of usual design, built up of 12"x12" timber.

A novel method of sealing the large working chambers was developed and used. It consisted in dividing the working chamber into four sections by bulkheads. The entire bottom up to the

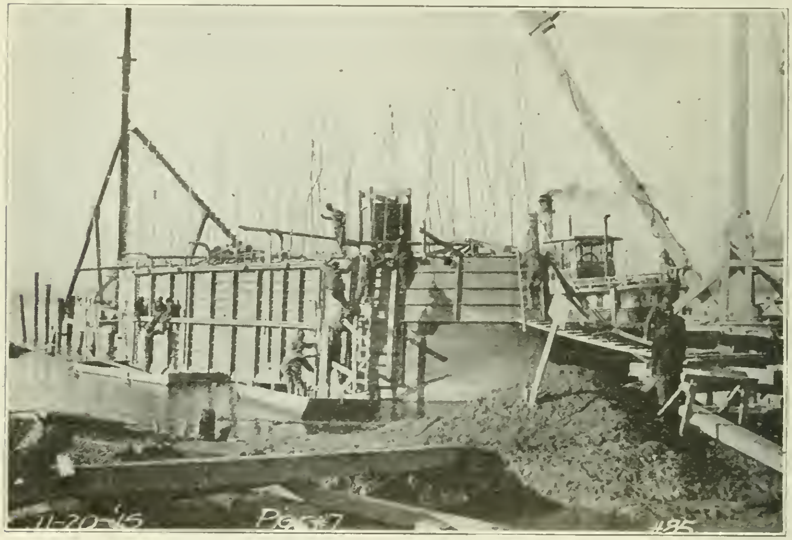


Fig. 15. Pier VII

cross struts was first concreted. The two end sections were next filled with concrete, and then the second and third sections successively. This permitted to ascertain for all sections but the third, that they were completely filled, by boring holes through the bulkheads. A free running wet mixture of concrete with small sized gravel was used in sealing.

The river caissons for Piers II to VI inclusive, were built on a pontoon and launched by sinking the pontoon, a similar method to that employed at Memphis. The caisson for Pier I was built on shore in place, and the caisson for Pier VII was also built in place on a fill made of brush and sand. The pontoon measured 65' x 120' horizontally. It differed from the one used at Memphis in that, instead of being in two sections longitudinally, so that the

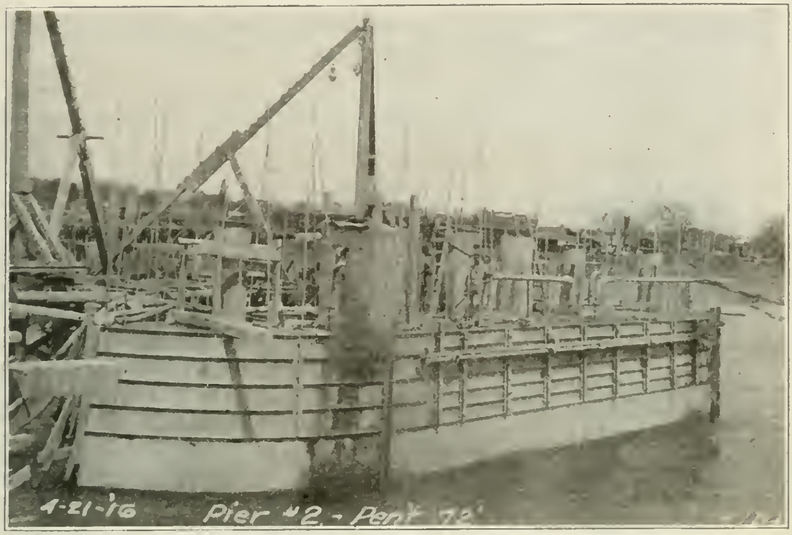


Fig. 16. Sinking Pier No. II, showing Concrete Forms

two halves could be separated and removed from under the caisson, it was provided with an end gate, for the purpose of submerging. Three water boxes were provided on each side of the pontoon, which, when filled, contained about 80 tons of water. This weight, when applied, served to sink the pontoon sufficiently

Fig. 17. Pier VII Finished

to clear it from the floating caisson, and allow the pontoon to be floated away. The same pontoon was used successfully for the five caissons mentioned.

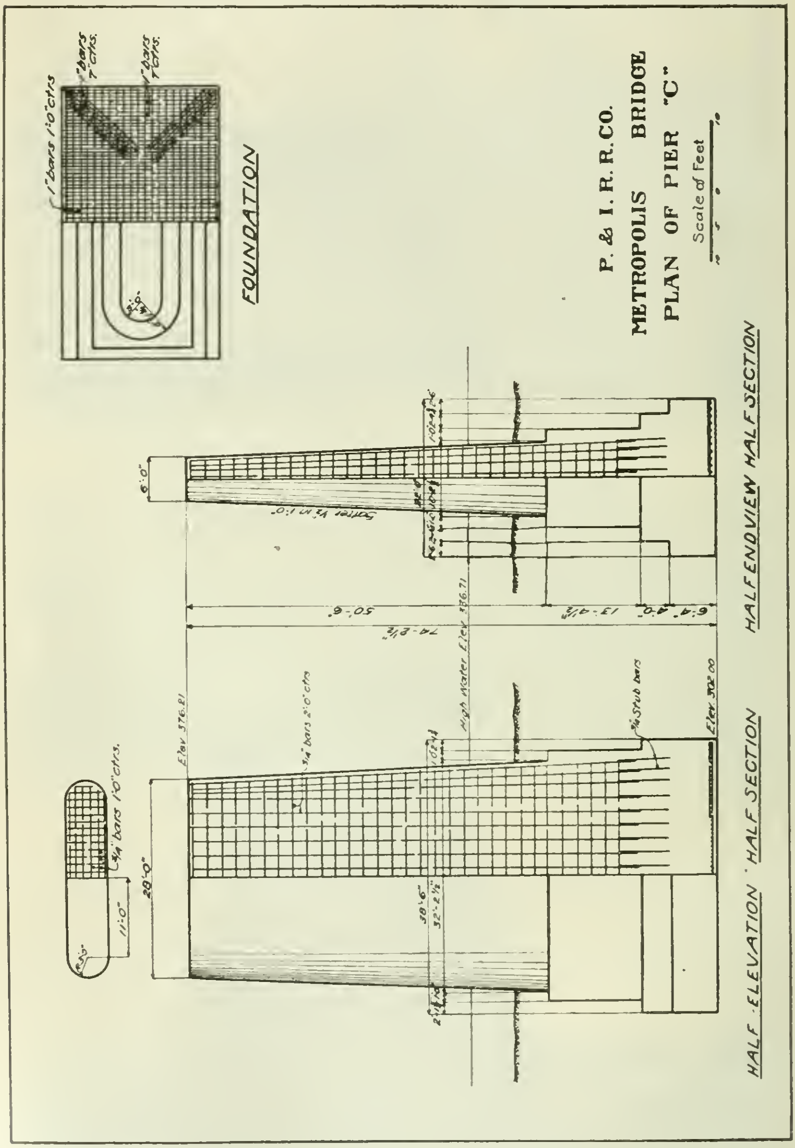


Fig. 25

In building caisson VII, which as mentioned was built in place, it was considered advisable to place its center line 21" nearer shore

than desired for final position. This was done to offset the crowding effect of the sloping bank on which it was built. After

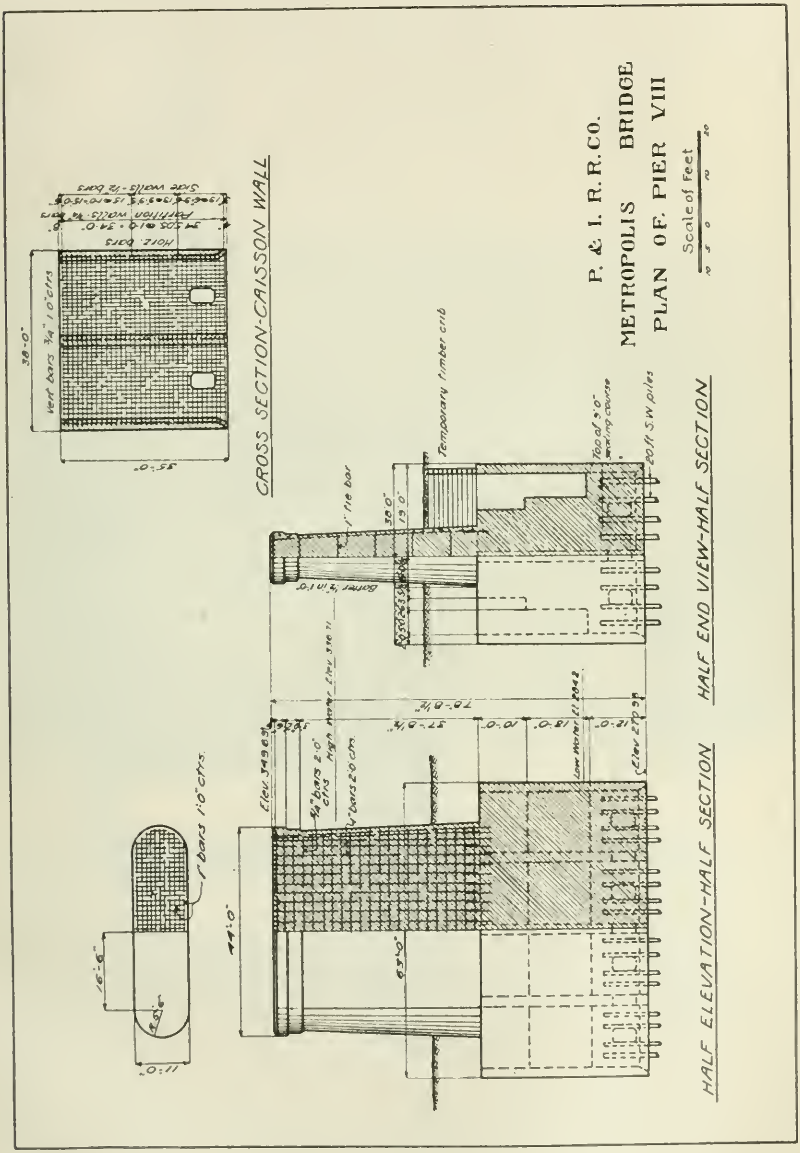


Fig. 26

the cutting edge penetrated the ground 16′, the caisson came to practically the true position, and no trouble was experienced in maintaining it there.

A great deal of thought and study was devoted to the question of material for the pier shafts. Granite facing with concrete

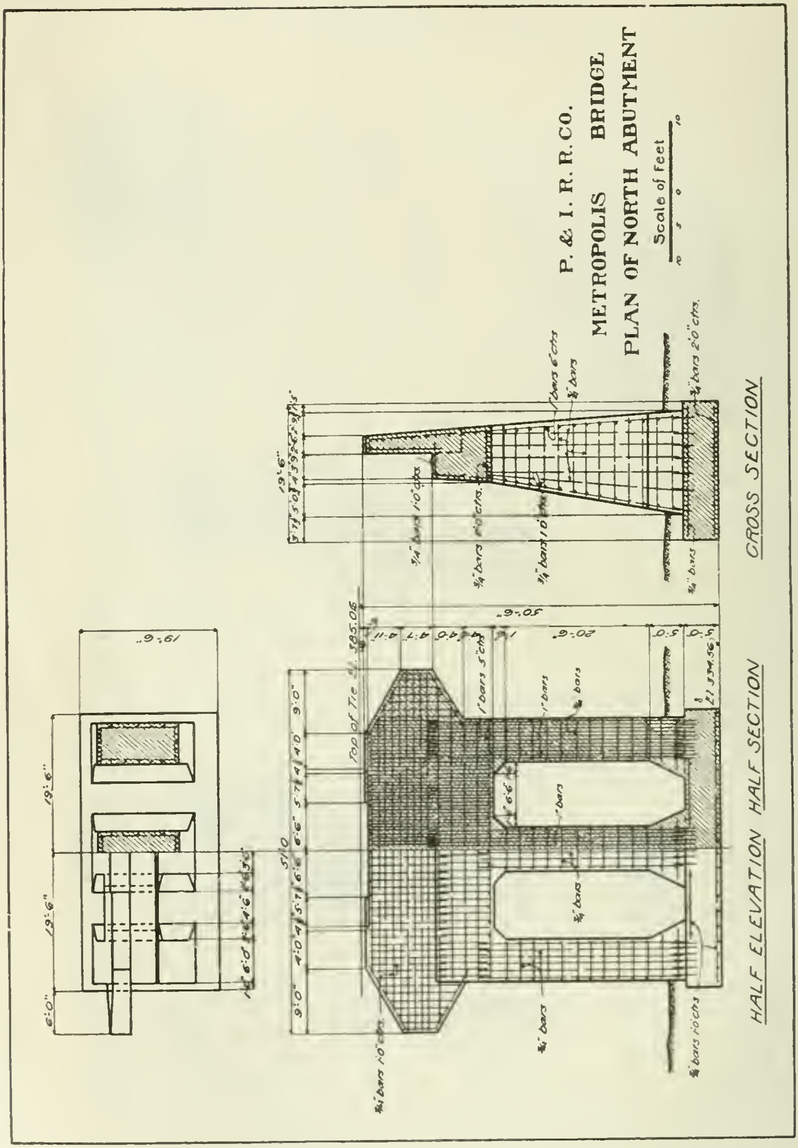


Fig. 27

backing was seriously considered, but finally it was decided to build the piers of concrete, although a precedent for such large

concrete piers in a stream was lacking. The accompanying Figures 18 to 24, show the general design of the piers. They also show the sinking record of each pier, foundation pressures, costs, etc. The typical reinforcement of pier shafts is shown on Figure 5. The upstream nose of each pier below the starling coping is provided with a steel angle to protect it from ice and drift. Steel forms were used for the shafts of the piers (Fig. 16).

Some time ago, it was considered that the weight of metal trusses increases approximately as the square of the span. In

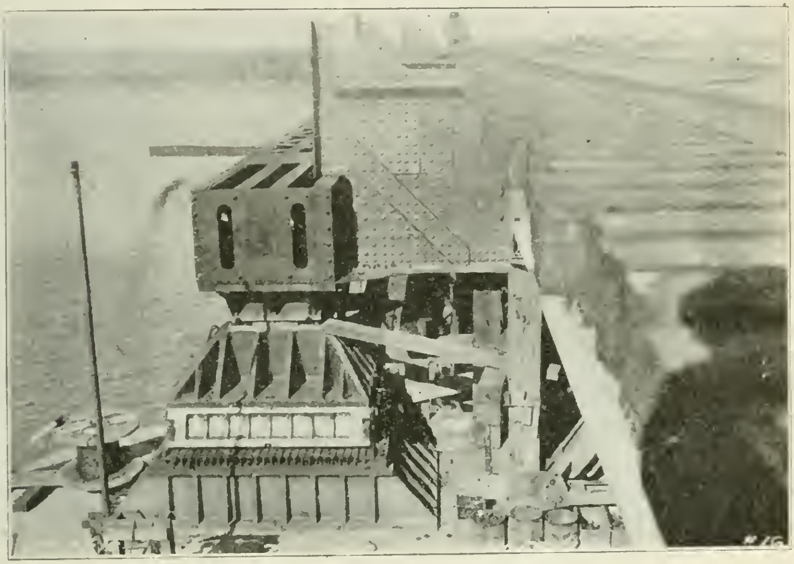


Fig. 30. 720-Foot Span, Expansion End Castings

spans of moderate length, this sometimes is a fair approximation, but as we learn how to build longer spans, this "rule of thumb" does not apply. In connection with a cantilever span of extra length, such as the one at Quebec, it was found by close analysis, that for spans in the neighborhood of 1800', the weight of trusses increases at a ratio proportional to between the third and fourth power of the span length. Without having gone through an analysis of what the increase would be for a 720' single span, the writer believes that this increase would not be much under a ratio corresponding to the cube of the span length. The longer the span, therefore, the greater the need of reducing its dead weight to a minimum. One of the chief sources of economy is, of course, a high grade material, which can sustain greater working stresses than the material used for the ordinary run of bridge work. The engineers of the Metropolis Bridge had, at the time when designs were begun, three

such grades of material to consider, High Carbon Steel, Mayari Steel, and Nickel Steel. Later, Silicon Steel was offered by a manufacturing firm, and was finally used for all compression members and for some of the tension members. Nickel Steel was retained for eye-bars.

The 720′ span, which is the longest simple span ever built, is of course, the most notable feature of the bridge. As we become better acquainted with the manufacture and properties of special high tensile alloys, and as methods of manufacture, handling and

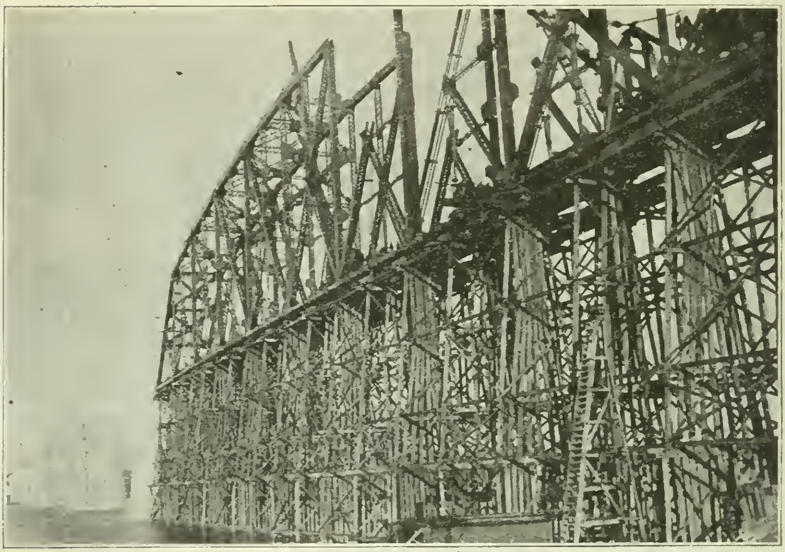


Fig. 31. Falsework of 720-Foot Span

transportation improve, so as to permit the use of heavier bridge members, the length of practicable spans increases. With that increase, arises the greater necessity for careful designing and a careful selection of proper materials to use.

With this end in view, comparative tests of large models of columns built of High Carbon Steel, Mayari, Silicon and Chrome Steels were made. The columns were designed to represent as nearly as possible the type of columns intended for the bridge, and their sections were kept within the limits of the 5,000-ton testing machine at Pittsburgh. The design of the test columns and the results of tests have been published in a pamphlet by the Bureau of Standards, and therefore only a general reference will be given here. Two designs of test columns were used.

Five columns of each design—ten in all—were built up of the various steels to be tested. Two of each design were of High

SINKING DATA

Date	Elev. of Cutting Edge N.E.	N.W.	S.W.	S.E.	Sinkage 24 Hr.	Sinkage Total	Penetration	Elev. of Ground N.E.	N.W.	S.W.	S.E.	Water Stage Gauge	Water Stage Elev.	Depth Immersed
July 19 1915	307.00	306.64	306.94	306.90		3.70	3.70	311.5	311.3	310.1	310.5	26.0	310.2	3.3
20	"	"	"	"		"	"	"	"	"	"	"	"	"
21						"	"					25.6	309.8	2.9
22						"	"					25.1	309.3	2.4
23						"	"					24.6	308.8	1.9
24						"	"					24.4	308.6	1.7
25	306.89	306.52	306.91	306.79	0.09	3.80	3.8					"	"	1.8
26	306.88	306.50	306.81	306.62	0.08	3.90	3.9					24.3	308.5	"
27	306.79	306.49	306.64	306.30	0.10	4.00	4.0					24.2	308.4	"
28	303.53	304.34	303.54	303.45	2.90	6.90	6.9					23.8	308.0	4.3
29	303.45	303.04	303.52	"	0.40	7.30	7.3					23.3	307.5	4.2
30	"	303.01	303.30	"	0.0	7.30	"					22.5	306.7	3.4
31	303.40	302.91	303.26	303.43	0.05	7.35	7.4					21.5	305.7	2.5
Aug 1	302.33	302.44	302.45	301.98	0.95	8.30	8.3					20.4	304.6	2.3
2	301.05	301.49	301.25	300.98	1.23	9.53	11.4	313.4	312.5	312.9	311.9	19.3	303.5	2.4
3	301.02	301.43	301.21	"	0.04	9.57	11.5	"	"	"	"	18.4	302.6	1.6
4	301.09	301.47	301.13	300.33	0.03	9.60	"					18.0	302.2	1.2
5	300.74	300.93	300.64	300.02	0.42	10.02	11.9					17.9	302.1	1.5
6	298.37	297.61	297.49	297.75	2.79	12.81	14.7					18.2	302.4	4.6
7	297.72	297.07	297.38	297.59	0.35	13.16	15.1					18.7	302.9	5.6
8	297.00	296.00	296.05	296.61	1.03	14.19	16.1	313.8	313.0	312.4	311.6	19.2	303.4	7.0
9	295.08	295.54	295.54	294.64	1.21	15.40	17.3	"	"	"	"	19.1	303.3	8.1
10	292.77	292.28	292.51	292.55	2.67	18.07	20.0					19.0	303.2	10.7
11	"	292.20	292.48	"	0.04	18.11	"					"	"	"
12	291.63	291.62	291.71	291.27	0.93	19.04	20.9					19.1	303.3	11.7
13	289.83	289.68	289.61	289.30	1.95	20.99	22.9					19.5	303.7	14.1
14	289.80	289.61	289.56	"	0.04	21.03	23.1	312.3	313.4	312.8	313.0	19.9	304.1	14.5
15	286.72	286.48	286.93	286.14	3.00	24.03	26.1	"	"	"	"	20.0	304.2	17.6
16	286.30	285.98	286.31	285.39	0.50	24.48	26.6					19.5	303.7	"
17	283.73	283.43	283.93	283.24	2.54	27.02	29.1					19.0	303.2	19.6
18	282.26	281.73	282.14	282.38	1.53	28.55	30.7					17.9	302.1	20.1
19	280.08	279.26	279.98	279.72	2.29	30.84	32.9					17.5	301.7	21.9
20	278.00	277.90	277.94	277.96	1.94	32.78	34.9					17.7	301.9	24.1
21	277.53	277.12	277.48	277.47	0.30	33.08	35.2					20.0	304.2	26.7
22	274.66	274.84	275.06	274.40	2.78	35.86	38.0					22.3	306.5	31.8
23	273.00	273.38	273.63	273.46	1.28	37.14	39.2					24.0	308.2	34.7
24	271.00	270.58	271.04	270.83	2.58	39.72	41.8					25.4	309.6	36.1
25	270.98	270.43	271.03	270.75	0.08	39.80	41.9					26.5	310.7	39.9
26	270.94	270.16	270.65	270.66	0.20	40.00	42.1					26.7	310.9	40.3
27	267.47	266.78	267.11	267.01	3.51	43.51	45.6					26.4	310.6	43.5
28	"	"	"	"	0.0	"	"					25.6	309.8	42.7
29	"	"	"	"	0.0	"	"					24.0	308.2	41.1
30	265.85	265.25	265.37	265.17	1.68	45.19	47.3					22.4	306.6	41.2
31	265.37	264.87	264.94	264.69	0.44	45.63	47.7					21.0	305.2	40.2
Sept 1	263.17	262.78	262.69	262.29	2.24	47.87	50.0					19.9	304.1	41.4
2	261.76	261.28	261.21	260.86	1.45	49.32	51.4					19.0	303.2	41.9
3	261.67	261.04	260.92	260.78	0.18	49.50	51.6					17.7	301.9	40.8
4	259.84	258.75	258.97	259.22	1.91	51.41	53.5					16.5	300.7	41.5
5	256.45	255.90	256.20	256.01	3.05	54.46	56.6					15.7	299.9	43.3
6	253.81	253.28	253.57	253.37	2.66	57.09	59.2					14.2	298.4	44.9
7	253.78	253.25	253.55	253.35	0.03	57.12	"					13.4	297.6	44.1
8	253.29	252.78	253.09	252.87	0.47	57.59	59.7	312.0	313.0	313.0	313.5	12.0	296.2	43.2
9	252.16	252.07	252.38	252.20	0.81	58.40	60.5	"	"	"	"	"	"	44.0
10	249.64	249.40	249.76	249.69	2.58	60.98	63.1					12.5	296.7	47.1
11	247.43	247.22	247.56	247.48	2.20	63.18	65.3					13.3	297.5	50.1
12	246.21	245.99	246.32	246.25	1.23	64.41	66.5					13.8	298.0	51.8
13	245.37	245.09	245.30	245.46	0.83	65.24	67.3					14.5	298.7	53.3
14	243.64	243.39	243.72	243.60	1.75	66.99	69.1					15.6	299.8	56.2
15	241.18	240.95	241.25	241.20	2.47	69.46	71.6					16.5	300.7	59.6
16	239.77	239.50	239.85	239.81	1.41	70.87	73.0					"	"	61.0
17	239.09	238.82	239.15	239.13	0.68	71.55	73.7					16.0	300.2	61.1
18	238.40	238.12	238.44	238.44	0.70	72.25	74.4					15.5	299.7	61.4
19	238.13	237.84	238.15	238.15	0.28	72.53	74.6					"	"	61.6
20	236.80	236.50	236.84	236.76	1.35	73.88	76.0					15.1	299.3	62.6
21	235.96	235.65	235.98	235.91	0.85	74.73	76.8					14.7	298.9	63.0
22	235.39	235.07	235.43	235.40	0.55	75.28	77.4					14.3	298.5	63.2
23	235.24	234.92	235.29	235.25	0.15	75.43	77.5					14.0	298.2	63.0
24	"	"	"	"	0.0	"	"					14.1	298.3	63.1
25	235.20	234.93	235.23	235.21	0.02	75.45	77.6					14.0	298.2	"
26	"	"	"	"		"	"					13.4	297.6	62.5
27	"	"	"	"		"	"					13.1	297.3	62.2
28	"	"	"	"		"	"					12.5	296.7	61.6

Date	Weight of Caisson-Tons: Timber	Conc.	Water and Earth	Miscl.	Total	Air Pressure Gauge: Plant	Cais.	Calc.	Reaction due to air pressure	Net Weight	Sq. ft. of friction surface	Tons per sq. ft. of friction surface	Material	Location	Remarks
July 19 1915	448			42	490										
20	"			"	"										
21															
22															
23															Tested with 10 lbs. air.
24															
25															
26		152			642										
27															Air on 3.00 P.M. today
28		608			1098	11	3	3	785	313	2060	0.15	Clay-sand	7"S, 3.5"E
29		992			1482	13	"	"	1020	462	2180	0.21	" "	4"S, 2.5"E
30		"			"					"	2230	0.35		4.5"S, 2"E
31		1446		45	1939	14	4		1050	889	2300	0.38		4"S "
Aug 1		1872		"	2363	15	"	4	"	1313	2380	0.55		3"S 4"E
2		2104			2597	"	"			1597	2900	0.55	Sand	3"S 3"E
3	497			48	2699					1599	2910	"	Clay		
4	"			"	"	16	5		1310	1339	2920	0.46	"		
5						17	6		1370	1079	3020	0.36			
6		2540			3085	18	9		1830	1255	3740	0.33		2"S 2"W	
7		3106			3651	19	8	6	2100	1551	3830	0.41	Blue clay	" 1"E	Finished concreting caisson section.
8		3560			4105				"	2005	4100	0.49	" "	" "	
9		"						7			4400	0.45		2.5"S 2.5"E	
10						20		8			5030	0.39		4"S 2.5"E	
11						21	9	"	2350	1755	5135	0.34			
12		4090			4635				"	2285	5295	0.43			
13		4370			4915	22		9		2565	5740	0.44	Clay-gravel	2"S 2"W	
14		4680	85		5310	"	10	"	2610	2700	5800	0.46	Gravel		
15		5376			6006	14	"	10	"	3396	6490	0.52	"	" "	Finished concreting 1st form section
16	549			55	6065	12				3455	6590	"		1"N 1"E	Changed air line 4" to 6"
17	"					12.5		12		"	7180	0.48			
18	582	5934		61	6662	14	12		3140	3522	7530	0.47	Gravel-sand	0.5"N 3"E	
19	615	"		67	6701	15	13	13	3400	3301	8000	0.41	Gravel-sand-clay	0.5"S 4.5"E	
20	"				"	14	"	14	"	"	8360	0.40	Sand-clay	2.5"S 3"E	
21		6404	768		7459	15				4454	8420	0.53	"	" 2.5"E	
22		6736	915	77	8343			15		4993	8930	0.55	Clay	" 2"E	
23		"	989	"	8412			16		5012	9170		"	3"S 3"E	
24		7093	1121		8906			17		5506	9640	0.57			
25		7802	"		9615	17.5	15		3930	5685	9660	0.59		2.5"S 3.5"E	Finished concreting 2nd form section
26						21	19		4970	4644	9930	0.45		3.5"S "	
27			1148		9642	20	"	19	"	4672	10340	0.45		2.5"S 3"E	
28						"	"			"				" "	
29		8082			9922					4952		0.48			Concreting 1st section of shaft
30		"	1250		10024	19		20		5059	10650			2"S 3.5"E	
31		8524	1260		10476	20	20	"	5240	5236	10730	0.49			
Sept 1			1400		10616	21	"	21	"	5376	11130	0.47		2"S 4"E	
2			1300		10716	"		"		5476	11410	0.48		2"S 3"E	
3						"	21	22	5500	"	11440	0.46		" "	
4		9088	1550		11330	22		"		5830	11800	0.49	Clay-gravel		
5		"	1600		11380	"		24		5880	12380	0.47		2"S 3.5"E	
6			1672		11452	27		25		5952	12740	0.50	Clay-sand-gravel	3"S 4"E	
7				81	11456	22	22	"	5750	5706	12750	0.45	" " "	3"S 5"E	
8			1706	"	11490	"				5740	12820	0.45		" 4"E	
9			1753		11533					5793	12960	0.45		2"S 3.5"E	
10			1936		11720	23	23	27	6030	5690	13280	0.43		2.5"S 3"E	
11			2083		11867	25	24	"	6280	5586	13670	0.39		" 2"E	
12			2172		11956	24		28	"	5676	13770			1"S "	
13			2212		11996	25				5716	13890			" "	
14			2351		12135	26	25	29	6550	5585	14020	0.40	Blue clay	1.5"S "	
15			2553		12337	22	22	30	5750	6587	14410		" "	4.5"S	
16			2645		12429	26	25	31	6550	5879	14680			3.5"S 1.5"E	
17			2690		12474	23	23	"	6030	6444	14760				
18			2738		12522	26	25	"	6550	5972	14860	0.39		4"S 1"E	
19			2757		12541	28	28		7340	5201	14910	0.35			
20			2850		12634	25	25	32	6550	6084	15100			4.5"S 2"E	
21			2908		12692	33	33	"	8650	4042	15210	0.28		6.5"S 1.5"E	
22			2946		12730	32	32	33	8390	4340	15290	"		5"S 2.5"E	
23			2956		12740	33		"	"	4350	15310		Sand	" 2"E	Landed-sealing at 9.00 P.M. yesterday
24			"		"	"							"	" "	Sealing
25						33	33		8650	4090	15320	0.27			"
26						"	"		"	"	"	"			"
27						33									
28						33									Finished sealing 1.00 P.M. Air off at 3.15 P.M.

DAILY PROGRESS PROFILE P

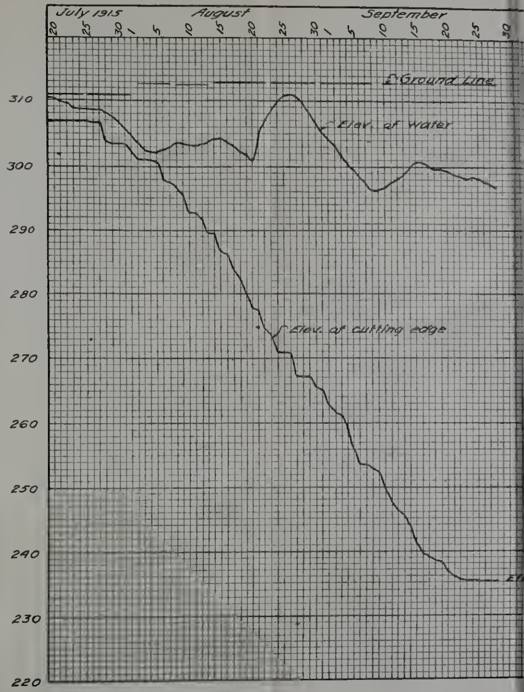


Fig. 18

PLATE IX

Western Society of Engineers.
Vol. XXIV, No. 2, February, 1919.
Modjeski—Metropolis Bridge.

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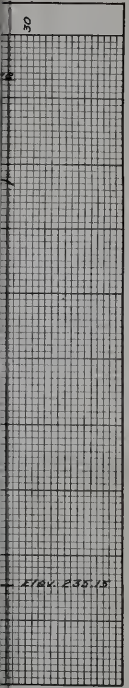
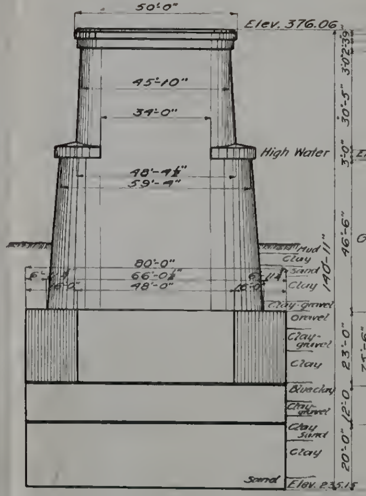
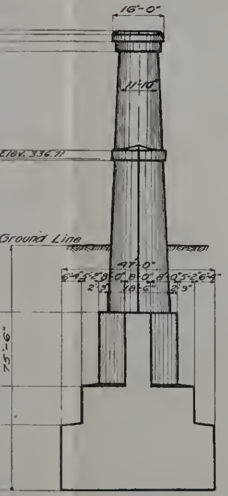




ELEVATION



END VIEW

QUANTITIES

Excavation		10634 Cu. yds.
Concrete :-		
1ST Section	2317	
2ND Section	1135	
3RD Section	1213	
Shaft	2441	
Total		7106 Cu. yds.
Timber-caisson and crib		325564 Ft. B.M.
Cement		11371 Bbls.
Corr. bars		148958 Lbs.

COSTS

	Overhead	Labor	Mat'l.	Total	Unit	Per cu. yd. concrete
Framing caisson and crib		22.02	32.30	54.32	M.ft.B.M.	$2.49
Excavation	0.36	1.70	0.53	2.59	Cu. yd.	3.88
Forms		0.25	0.14	0.39	Sq. ft.	0.59
Reinforcing		0.39	1.52	1.91	Cwt.	0.40
Concrete :-						3.74
Working chamber	0.32	1.59	3.31	5.22		
1ST 2ND 3RD Sections	0.31	0.47	2.53	3.31		
Shaft	0.32	0.33	3.30	3.95		
Overhead-equipment etc.						2.02
Total						13.12
Total cost of Pier	$93300.09					

MAXIMUM FOUNDATION LOADS

Direct Load	5.14
Horizontal Load	2.30
Total	7.44 Tons per sq. ft.

NOTES

Cutting edge laid	6-22-15
Caisson sealed	9-27-15
Total days sinking	57
Delays	0
Actual days sinking	57
Average per day	1.2 ft.
Max. per day	3.51 ft.
Max. immersion	63.2 ft.
Max. air pressure	33 Lbs.
Pier completed	12-31-13

P. & I. R. R.

BRIDGE NO. 1.72 OVER OHIO RIVER

—AT—

METROPOLIS, ILL

CONSTRUCTION RECORD

—OF—

PIER No. 1

Metropolis, Ill. July 1, 1917

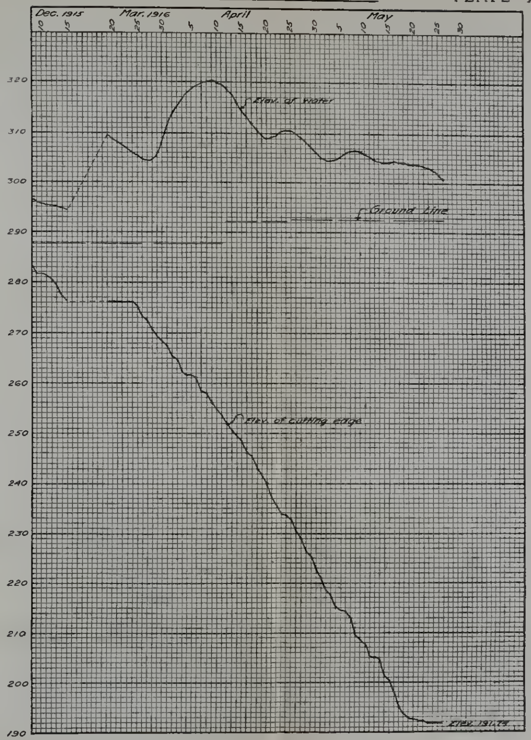
Fig. 19

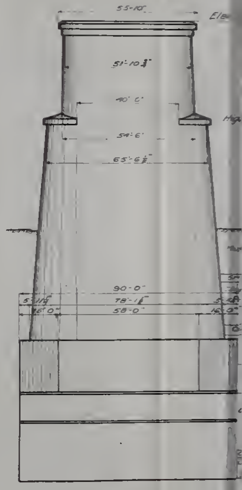
PLATE X

SINKING DATA

Date	Elev. of Cutting Edge				Sinkage		Penetration	Elev. of Ground				Water Stage		Depth Immersed	Weight of Caisson-Tons					Air Pressure			Reaction due to air pressure	Net Weight	Sq. ft. of friction surface	Tons per sq. ft. of friction surface	Material	Location	Remarks
	N.E.	N.W.	S.W.	S.E.	24 Hr	Total		N.E.	N.W.	S.W.	S.E.	Gauge	Elev.		Timber	Concrete	Water and Earth	Miscl.	Total	Gauge Plant	Gauge Caisson	Calc.							
Dec. 8 '15	284.13	282.81	281.37	283.59		5.66		287.4	288.4	285.7	289.5	12.2	296.4	13.3	721	1920		14	2655	8	4	6	1260	1395	1650	0.85	Soft mud	6" S. 0" W.	Air on at 12 P.M. Dec. 7th. Men in at 8 A.M.
9	283.75	282.21	279.84	282.23	1.38	7.04		"	"	"	"	11.8	296.0	19.2	"	"		"	"	10	6	"	1890	765	2050	0.37	" "	7" S. 1" W.	
10	[illegible]		279.80	282.28	0.02	7.06						11.4	295.6	13.9		"		"		"	"	"			2060	"		" "	
11	[illegible]	281.73	[illegible]	281.39	0.32	7.38						11.1	295.3	14.1	817	"		"	2745	"	7	"	2205	340	2210	0.29	"	8" "	
12	[illegible]	280.36	279.78	280.53	0.83	8.41						11.0	295.2	19.8	"			"	"	"	"	"	"	"	2960	0.22	" "	5" " 2" "	
13	[illegible]	278.75	278.73	278.48	1.30	9.71						10.8	295.0	15.9	"	2188		"	3013	"	"	7	"	808	2890	0.28	" "	11" " " "	
14	276.79	276.87	277.21	277.25	2.06	11.77						10.6	294.8	17.0	"	3580		"	4505	"	"	8	"	2200	3920	0.64	Clay	14" " 3" "	
15	275.28	276.45	276.82	276.02	0.89	12.66						10.2	294.4	18.3	"	4956		"	5781	"	"	8	"	3781	3700	1.56	"	15" " " "	Air off at noon. Moved to Pier No 3
Mar. 19 '16	275.21	276.40	276.77	276.01	0.05	12.71						23.2	309.4	33.3	"	"		"	"	16	19	14	4410	1371	3710	0.37	Mud	" "	Air on at 9.00 P.M. yesterday
20	275.19	276.37	276.72	275.94	0.04	12.75						24.7	308.9	32.8	"	6456	393	"	7674	"	16	"	5090	2630	3720	0.71	" & gravel	13" S. 3" W.	Work stopped at 8.00 A.M.
21	"	"	"									24.0	308.2	32.2	"	8078	"	20	9302	"	"	"		4262	"	1.15	" "	" "	No sinking. Building 3rd form section
22			"	"		"						23.3	307.5	31.5	"	"	"	"	"	"	"	"	"			"	" "	"	" " "
23		"	"	"								22.5	306.7	30.7	"	"	"		"	"	"	13	"	"	"	"	" "	" "	" " "
24												21.8	306.0	30.0	"	"	"		"	"	"	"	"	"	"	"	" "	" "	" " "
25	[illegible]	275.24	275.11	275.15	0.97	13.72						21.1	305.3	30.2	900	"	279		9272	18	"	"	"	4232	4000	1.06	Clay-gravel	" 8" "	Sinking resumed at 4.00 P.M. yesterday
26	[illegible]	[illegible]	273.26	273.03	1.96	15.68						20.5	304.7	31.6	"	"	335		9333	16	12	14	3780	5553	4600	1.20	" "	12" " 4" "	
27	273.57	273.49	272.83	271.33	0.81	16.49						20.1	304.3	32.0		"	354		9352	18	15	"	4730	4622	4830	0.95	" "	9" " " "	
28	271.06	271.06	269.50	269.95	1.93	18.42						20.3	304.5	33.1		"	447		9495	19	19	15	4410	5035	5400	0.93	" "	" 3" "	
29	[illegible]	270.25	268.05	268.91	0.99	19.41						21.6	305.8	36.4		"	656		9656	"	15	16	4730	4926	5680	0.87	" "	7" " "	
30	269.85	269.03	266.47	267.77	1.11	20.52						24.0	308.2	39.9		3764	933		11617	22	16	17	5090	6577	6000	1.09	Clay-sand-gravel	6" "	
31	268.30	267.70	[illegible]	267.22	0.94	21.46						27.3	311.5	44.2		"	1628		12312	29	18	18	5680	6632	6250	1.06	" "	8" "	
Apr. 1	266.38	[illegible]	263.93	264.50	2.05	23.51						29.6	313.8	48.5		"	2017	32	12713	"	"	21	"	7033	6900	1.02	" "	6" " "	
2	[illegible]	265.55	263.41	263.94	0.53	24.04						31.1	315.3	50.5		10626	1821	"	13379	"	21	22	6600	6779	7000	0.97	" "	" "	
3	262.87	263.03	261.00	261.34	2.70	26.74						32.4	316.6	54.5		"	2174		13732	26	29	29	7580	6152	7720	0.80	" "	" "	
4	262.37	262.48	260.48	260.84	0.52	27.26						33.5	317.7	56.2		"	2315		13873	25	25	24	7880	5993	7850	0.76	" "	" "	
5	262.36	"	260.43	260.83	0.02	27.28						34.4	318.6	57.1		11748	2395		15075	"	"	25	"	7195	7860	0.91	" "	" "	Concreting 1st shaft section
6	262.05	261.80	260.16	260.05	0.51	27.79						35.0	319.2	58.2		11810	2651		15353	27	24	"	7580	7813	7990	0.98	" "	" "	
7	[illegible]	259.03	257.10	257.35	2.82	30.61						35.5	319.7	61.5		"	3151		15892	29	28.5	26	9000	6892	8720	0.79	Clay	5" " 1" "	
8	[illegible]	258.63	256.77	257.75	0.28	30.89						35.8	320.0	62.1		"	3171		15912	"	"	27	"	6912	8800	"	" "	" "	
9	256.53	256.77	255.19	255.28	1.95	32.84						35.9	320.1	64.1		"	3933		16175	"	27	28	8500	7675	9320	0.82	" "	" 2" "	
10	255.20	254.15	254.04	254.82	1.41	34.25						35.7	319.9	65.4		"	3606		16398	"		"	"	7898	9700	0.81	" "	" "	
11	[illegible]	252.35	[illegible]	254.13	0.91	35.16						35.2	319.4	65.8		12340	3697		16969	31.5	30	"	90	7519	9900	0.76	Clay-sand	" "	Concreting
12	[illegible]	251.28	[illegible]	252.43	1.67	36.83	40.8	291.1	291.0	293.2	293.6	34.3	318.5	66.5		"	3859		17131	32		23	"	7681	11000	0.70	" "	4" "	
13	251.11	250.54	250.27	250.27	1.30	38.13	42.1	"	"	"	"	33.2	317.9	66.7		12760	3949		17691	32.5	32	"	10100	7591	11900	0.66	" "	" "	Concreting
14	249.51	249.29	[illegible]	[illegible]	1.49	39.62	43.6					31.8	316.0	66.8		12826	4039		17797	32	30	"	9950	8347	11800	0.71	" "	3" " "	
15	248.57	248.00	247.77	248.27	1.03	40.65	44.6					30.4	314.6	66.5			4046		17804	"	31.5	"	9930	7874	12000	0.65	" "	2" " "	
16	246.17	246.01	245.84	245.93	2.16	42.81	46.3					29.1	313.3	67.3		"	4260		18018	"	31	"	9800	8218	12300	0.67	" "	" "	
17	245.78	[illegible]	245.30	245.58	0.48	43.29	47.3					27.8	312.0	66.3		"	4010		17768	"	"	"		7968	12500	0.63	" "	" "	
18	[illegible]	242.71	242.78	[illegible]	2.58	45.87	[illegible]					26.5	310.7	67.8		"	4477		18235	33	32	"	10100	8135	13100	0.61	" "	" "	
19	241.71	240.80	241.24	241.75	1.56	47.43	51.4					25.3	309.7	68.3		"	4610		18368	"	31.5	30	9930	8438	13400	0.63	" "	" "	
20	240.18	239.59	239.58	240.19	1.50	48.93	52.9					24.8	309.0	69.1		"	4778		18536	"	"	"	"	8606	13700	"	" "	" "	
21	237.40	236.83	236.86	237.36	2.76	51.69	55.7					24.9	309.1	72.0		"	5247		19005	34	32	31	10100	8905	14200	"	" "	" 1" "	
22	235.73	235.37	235.37	235.78	1.33	53.22	58.2					26.3	309.5	73.9		"	5527		19385	"	"	32	"	8885	14800	0.60	Clay-sand-gravel	" "	
23	233.92	233.66	233.62	233.85	1.82	55.04	59.0					26.9	310.2	76.4		"	5909		19667	33	34	33	10700	8967	14900	"	" "	3" " 3" "	
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		"	[illegible]		[illegible]	"	"	32	"	[illegible]	[illegible]	"	" "	[illegible]	
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60.6	291.6	291.3	293.6	293.3	26.3	310.5	77.8		13296	6220	40	20956	"	"	34	"	9756	15000	0.65	" "	[illegible]	Concreting
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		"	[illegible]		[illegible]	[illegible]	[illegible]	35	10900	[illegible]	15500		" "	[illegible]	
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		"	[illegible]		[illegible]	[illegible]	[illegible]	"	11600	[illegible]	15700	0.63	" "	[illegible]	
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		"	[illegible]		[illegible]	[illegible]	[illegible]	36	"	[illegible]	16200	0.61	" "	[illegible]	
29	225.32	225.33	225.07	225.32	0.78	63.53	68.0					23.1	307.3	82.0		13716	7280		21936	39	39	"	12300	9636	16300	0.59	" "	2" N. 5"	Concreting
30	222.66	222.56	222.53	222.89	2.61	66.14	70.6					21.9	306.1	83.4		"	7606		22262	34	33	"	10400	11862	16700	0.71	" "	" " 2" "	
May 1	220.80	220.59	221.04	221.00	1.71	67.85	72.4					20.8	305.0	84.1		"	7783		22439	"	"	"	"	12039	17000	0.69	" "	" " 1" "	
2	218.21	218.45	218.48	218.44	2.56	70.41	74.9					20.3	309.5	86.1		"	8185		22891	35	34	37	10700	12141	17400	0.70	" "	4" S. 4" "	
3	217.82	217.83	217.54	217.60	0.67	71.08	75.6					20.1	309.3	86.6		"	8291		22997	39	39	38	12300	10647	17500	0.61	" "	1" " 3" "	
4	[illegible]	[illegible]	214.96	215.05	2.75	73.83	78.3					20.5	309.7	85.7		"	8812		23968	40	"	39	"	11168	17900	0.62	" "	" "	
5	[illegible]	214.70	214.46	214.72	0.38	74.21	78.7					21.0	305.2	90.6		"	8938		23594	"	"	"	"	11294	18000	"	" "	N. "	
6	214.31	214.33	214.21	214.22	0.32	74.53	79.0					21.8	306.0	91.7		14256	9078		24274	"	"	40	"	11374	18050	0.66	" "	0" "	Concreting
7	213.14	213.13	213.10	[illegible]	1.24	75.77	80.2					22.2	306.4	93.4		"	9345		24591	"	"	"	"	12291	18200	"	" "	1" S. 4"	
8	209.59	209.55	209.49	209.20	3.59	79.36	83.9					22.3	306.5	97.1		"	10003		25199	"	"	42	"	12899	18800	0.68	" "	0 3"	
9	208.71	208.82	208.72	208.40	0.78	80.14	84.6					22.1	306.3	97.6		"	10105		25301	45	45	"	14200	11101	18900	0.58	" "	2" S.	
10	207.85	207.91	207.88	207.46	0.86	81.00	85.0					21.7	305.9	98.1		"	10220		25416	"	"	"	"	11216	19000	0.59	" "	" 1"	
11	205.33	[illegible]	205.28	204.40	2.81	83.81	88.3					21.1	305.3	100.3		14662	10699	42	26253	"	"	43	"	12053	19500	0.61	" "	" "	Concreting - Sinking test holes.
12	205.32	"	205.25	[illegible]	0.0	"	"					20.5	304.7	99.7		"	10559	"	26158	"	"	"	"	11958	"	"	" "	" "	Test shows yellow sand at 197.5. White at 194.0
13	205.15	204.68	205.05	204.16	0.23	84.04	88.5					20.1	304.3	99.5		"	10576		26180	"	44	"	13900	12280	19550	0.63	" "	" "	
14	201.77	201.45	201.26	200.90	3.42	87.46	92.0					19.9	304.1	102.6		15034	11191		27167	"	"	44	"	13267	20100	0.66	" "	4" " 6" "	Concreting
15	200.80	200.00	200.50	199.77	1.07	88.53	93.0					20.0	304.2	103.3		"	11981		27957	46	"	45	"	13557	20300	0.63	" "	2" " 6"	
16	198.22	197.98	198.38	197.19	2.33	90.86	95.4					20.1	304.3	106.4		"	11916		27892		45	46	14200	13692	20600	0.61	Clay-sand	3" " 2" E.	
17	195.29	[illegible]	195.47	194.51	2.93	93.79	98.3					20.0	304.2	109.2		"	12235		28271	46.5	"	47	"	14071	21100	0.66	" "	4" N. 0	
18	194.03	193.55	193.39	193.10	1.34	95.13	99.6					"	"	110.5		"	12525		28501	49	48	48	15500	13001	21300	0.61	" "	2" S. 2" W.	
19	193.35	192.84	193.09	192.23	0.79	95.92	100.4					19.8	309.0	111.1		"	12645		28621	49.5	49	"	15600	13021	21900	"	" "	5" " "	
20	193.08	192.59	[illegible]	191.96	0.26	96.18	100.7					[illegible]	303.8	111.2		"	12626		28602	"	"	"	"	13002	21500	0.60	" "	" "	Sinking test wells.
21	192.67	192.22	192.44	191.61	0.38	96.56	100.1					19.5	303.7	111.5		15374	12736		29052	50	"	"	15750	13302	21600	0.61	" "	" "	" "
22	192.59	192.21	192.37	191.68	0.03	96.59	"					19.4	303.6	111.4		"	12720		29036	"	50	"	"	13286	"	"	" "	4" " "	" "
23	192.18	191.79	192.01	191.31	0.39	96.98	101.5					19.0	303.2	"		"	12748		29064	"	"	"	"	13314	21650	"		" 1"	Started sealing at 8.00 A.M.
24	192.15	191.76	"	"	0.01	[illegible]	"					18.9	302.6	110.8		"	"		"	"	"	"	"	"	"	"			
25	"	"	191.98	191.30	0.01	97.00	"					17.6	[illegible]	110.0		"	"		"	"	"	"	"	"	"	"			
26	192.08	191.71	191.99	191.20	0.06	97.06	[illegible]					[illegible]	[illegible]	[illegible]		"	"		"	"	"	47	"	"	21660	"			Finished sealing at 6.00 P.M. Air off at 7.00 P.M.

DAILY PROGRESS PROFILE





ELEVATION

Fig. 19

PLATE X

Western Society of Engineers.
Vol. XXIV, No. 2, February, 1919,
Modjeski—Metropolis Bridge.

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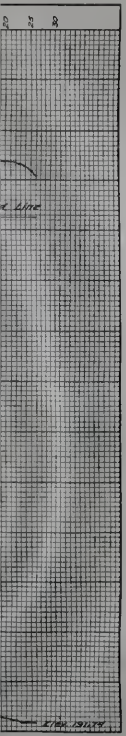

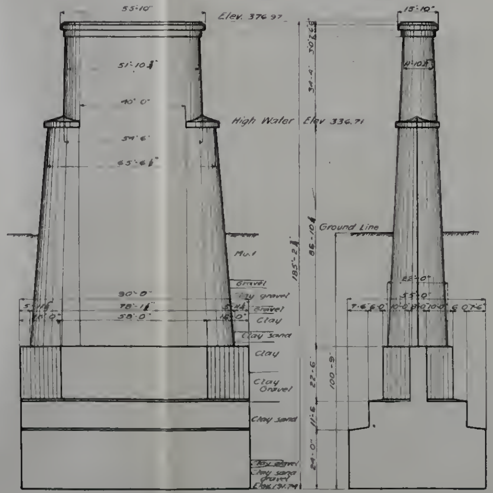

ELEVATION

END VIEW

QUANTITIES

Excavation		17840 Cu. yds.
Concrete :-		
1st Section	3234	
2nd Section	1520	
3rd Section	1977	
Shaft	4850	
Total		11581 Cu. yds.
Timber-caisson and crib		416117 Ft. B.M.
Cement		16744 B'bls.
Corr. bars		221508 Lbs.

EXTRA WORK - Included in above amounts

Excavation	4314 Cu. yds.
Concrete-shaft	695 Cu yds.
Cement	1220 B'bls.
Corr. bars	18000 Lbs.

COSTS

	Overhead	Labor	Mat'l.	Total	Unit	Per. cu. yd. concrete
Framing caisson and crib		26.08	31.98	58.06	M.Ft B.M.	
Pontoon				7.10	...	$2.34
Excavation	0.15	2.09	0.48	2.72	Cu. yd.	4.20
Forms		0.13	0.10	0.23	Sq. ft.	0.37
Reinforcing		0.20	1.53	1.73	Cwt.	0.30
Concrete :-					Cu. yd	3.15
Working chamber	0.20	1.83	3.06	5.09		
1st-2nd-3rd Sections	0.20	0.21	2.21	2.62		
Shaft	0.20	0.24	3.00	3.44		
Overhead-equipment etc.						2.06
Total						12.42
Total cost of Pier	$145765.16					

NOTES

Cutting edge laid	10-10-15
Caisson sealed	5-25-16
Total days sinking	167
Delays	100
Actual days sinking	67
Average per day	1.37 ft.
Max. per day	5.42 ft.
Max. immersion	111.5 ft.
Max. air pressure	50 Lbs.
Pier completed	7-14-16

MAXIMUM FOUNDATION LOADS

Direct Load	5.54
Horizontal Load	3.31
Total	8.85 Tons per sq. ft.

P.& I.R.R.

BRIDGE NO. 1.72 OVER OHIO RIVER

AT

METROPOLIS, ILL.

CONSTRUCTION RECORD

OF

PIER No. 2

Metropolis, Ill. May 1 1917

SINKING DATA

Elev of ground N.E.	N.W.	S.W.	S E	Water Stage Gage	Elev	Depth Immersed	Weight of caisson-tons Timber	Conc	Water and Earth	Misc.	Total	Air pressure Gauge Plant	Cais	Calc.	Reaction due to air pressure	Net weight	Sq.ft. of friction surface	Tons per sq. ft. of friction surface	Material	Location	Remarks
278.8	280.2	279.0	278.1	10.2	299.4	18.0	610	4358		19	4982	11	9	8	3121	1861	771	2.41	Mud-gravel	3'N. 3'W.	Air on at 4.00 P.M. Dec. 19-1915
"	"	"	"	10.4	299.6	18.8	619	5338		"	5971	"	"		"	2850	948	3.02	" "	" "	
				14.7	298.9	25.0	"	5778			6411	12	10	11	3468	2943	1518	1.93	Sand "	15'N. "	No work done today
																	"				
				31.5	317.7	44.1		10804	1929	20	12872	22	20	19	6935	3937	2247	2.64	Sand-gravel	7'N. 6'	Men in caisson 4.00 P.M. yesterday
				33.4	317.6	50.2		11109	1841	"	13509	23	23	22	7975	5609	3477	1.61	"	15'N N.	Men out 8.00 A.M. today
								"													
				39.2	323.4	57.0			2289		14032	26	25	25	8667	5365	3477	1.54	Coarse sand	No location	Men in 2.00 P.M. placing sand bags. Mtl.
				39.0	323.2	59.2			2273		14016	29	27	26	9372	4644	3780	1.49	" "	" "	scour at upstream end of caisson
				39.1	323.3	62.2			2281		14029	28	29	27	8322	5702	4500	1.26			
				39.7	323.9	64.1			2328		14051	"	"	26	"	5729	5370	1.07			
				40.0	324.2	68.7			2353		14078	29	29	28	10055	4023	5760	0.70			Men out at 11.00 P.M.
																					Air off at 2.00 P.M. yesterday.
																					No work done account high water.
263.3	281.1	270.0	262.6	24.3	306.5	44.0		12326	1806	21	14772	25	23	22	7975	6797	2850	2.37	Clay-gravel-sand	3'S. 2'W.	Men in 8.00 A.M. today Conc. 1st section
"	"	"	"	24.8	309.0	49.6		...	"	"	"	"	"	"	"	"	"	"	" " "	" 1'W	of shaft.
				25.8	310.0	51.3			1872		14848	26	24		8322	6526	3090	2.12		...	
				26.6	310.8	53.1			2113		15079	27	25	23	8667	6412	3400	1.88		5'S. 15'W.	
				26.9	311.1	55.4			2294		15260	28	"	24	"	6593	4000	1.65		4'S. 1'W.	
				27.0	311.2	56.7			2396		15362	28	26	25	8915	6447	4350	1.48		6'S. "	
				26.8	311.0	56.5															
				26.7	310.9	57.3			2625		15591	28	26	25	8915	6676	4610	1.49		3'S. 3'E.	
						59.6		12920	2896		16456	29	27	26	9372	7084	5290	1.39		" 4.5'E.	
						60.3		"	2979		16539	30	"	"	...	7167	5500	1.30		4'S. "	
				26.6	310.8	61.9			3150		16710	31		27		7330	6000	1.23		" 3'W.	
				26.3	310.5	63.4			3327		16887	"		"		7515	6350	1.15		"	
				26.1	310.3	64.3		13452	3412	32	17515			28		8193	6600	1.24		16'S. 15'E.	Location taken on top of concrete
				25.9	310.1	66.4			3648	"	17751	32	29	29	10055	7676	7180	1.07		20'S. 18'E.	
				25.8	310.0	66.7			3684		17787	"	"	"	...	7732	7590	1.02		8'S. 13'E.	
				25.5	309.7	67.8			4290		18393		30			8338	7900	1.06		7'S. "	
					"	68.8			4430		18533			30	10402	8131	8200	0.99			
				25.2	309.4	69.6															
																					Air off at 5.00 P.M. yesterday
				27.3	311.5	73.9			3191		19972	32	30	32	10402	9570	8900	1.07		10'S. 19'E.	Men in 8.00 A.M. 29th
				29.6	313.8	79.5		19718	3751		21120	34	32	34	11096	10024	9600	1.04			
				31.7	315.9	81.5		15092	6446		22105	36	35	35	12136	10049	10000	1.00			
				32.8	316.0	84.8			6913		22656	"	"	37	...	10520	10500	"			Men out at 8.00 A.M.
				16.7	300.9	69.1		13408	4972		21531			30							Air on 4.00 A.M. Men in at 8.00 A.M.
				16.1	300.3	69.8			3017		21516	32	30		10402	11174	10700	1.03		15'S. 20'E.	
				15.9	[illegible]	72.3			3135		21714	34	31	31	10799	10915	11350	0.95		14'S. 18'E.	
				15.8	[illegible]	74.3			3481		22040	35	32	32	11096	10944	12000	0.91		11'S. 16'E.	
				[illegible]	[illegible]	[illegible]			3973		22532		33	33	11442	11090	12440	0.89		6'S. 15'E.	
				18.7	[illegible]	[illegible]			[illegible]		[illegible]			36	...	12362	12940	0.94	Blue clay		
				20.0	[illegible]	[illegible]			[illegible]		[illegible]	36	35		12136	11833	...	0.91	" "		
				[illegible]	[illegible]	[illegible]			[illegible]		24104		34	37	11789	12320	12950	0.94			Using dynamite in clay
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]					12678	13200	0.95		4'S. 13'E.	
				[illegible]	[illegible]	[illegible]			[illegible]		24267					12658	13200	0.95		3.5'S. "	
				[illegible]	[illegible]	[illegible]			8082		[illegible]	35	33	38	11442	13193	13500	0.97		4.5'S. 8.3'E.	
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	36	33		11789	12852	13540	0.93			
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	38	35		12483	12179	13560	0.90		2'S. 9'E.	
				21.7	[illegible]	[illegible]			[illegible]		[illegible]				...	12877	13950	0.90		1'S. 10'E.	
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]			39		12667	14300	0.87		" 11'E.	
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	38	36	40		13036	14620		Blue clay-sand	6'N. 5'E.	
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	39		41		13766	15210	0.90	"	3.5'S. 3.5'E.	
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	41	40	43	13836	13129	16020	0.82		8'S. 11'E.	
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	42	41		14190	13004	16230	0.80			
				[illegible]	[illegible]	[illegible]		15762	[illegible]		[illegible]			44		[illegible]	[illegible]	0.81			
				[illegible]	[illegible]	[illegible]		16262	[illegible]		[illegible]			45		[illegible]	[illegible]	0.80		25'S. 9'E.	
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	43	42		14510	13740	17060				
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	"	"	46		14190	17100			19'S. 3.5'E.	
				23.5	307.7	108.6			[illegible]		[illegible]	45	44	47	15220	13810	18200	0.76		3'S. 2'E.	
				22.8	307.0	110.2			[illegible]		[illegible]	38	36	48	13910	13996	18700	0.75	Sand	15'N. 10'E.	Started sealing 4.00 P.M. today
				[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	"	...	12236	18800	0.67	"	10'N. 8.5'E.	
				21.8	306.0	109.5															Finished sealing 7.15 A.M. today Air off 8.00 A.M.

DAILY PROGRESS PROFILE

PLATE

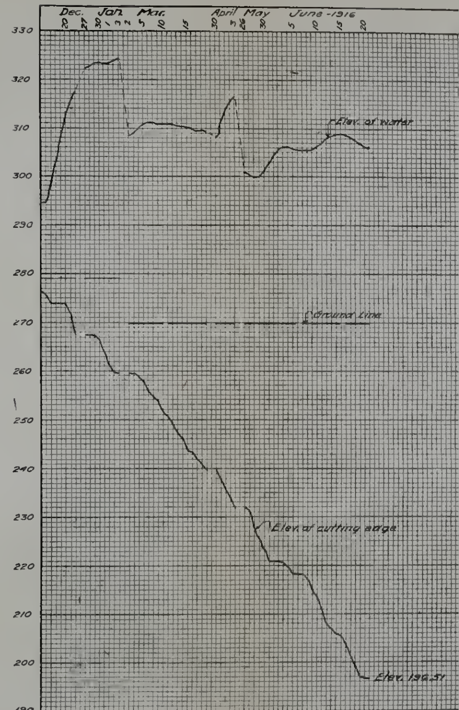

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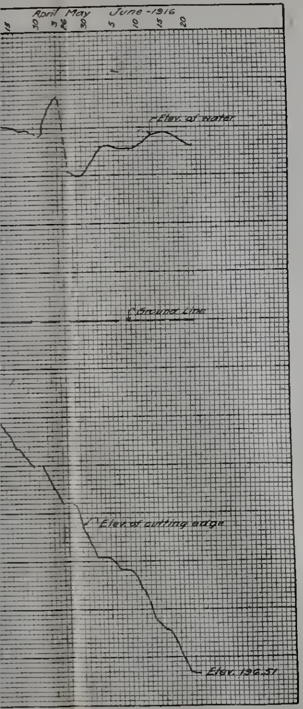
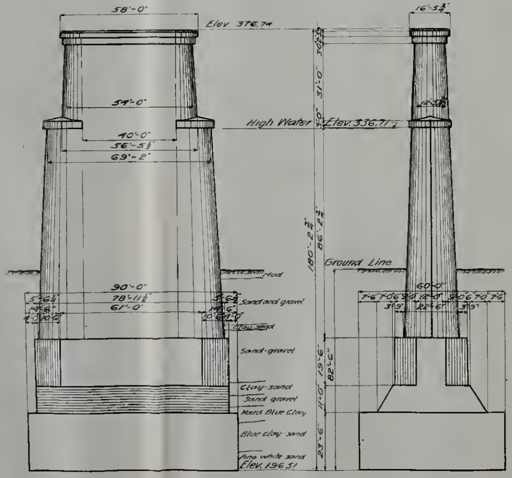
Fig. 20

PROGRESS PROFILE PLATE. XI





ELEVATION

END VIEW

QUANTITIES

Excavation		16648 Cu. Yds.	
Concrete:-			
1st Section	3720		
2nd Section	1230		
3rd Section	1655		
Shaft	4985		
Total		11590 Cu. Yds.	
Timber-caisson and crib		421592 Ft. B.M	
Cement		17618 Bbls	
Corr bars		212775 Lbs.	

EXTRA WORK-Included in above amounts

Excavation	3697 Cu. Yds.
Concrete-shaft	460 Cu. Yds
Cement	578 Bbls.
Corr bars	10000 Lbs

COSTS

	Overhead	Labor	Mat'l.	Total	Unit	Per cu yd. concrete
Framing-caisson and crib		31.17	4045	7162	M.Ft B M	
Pontoon				760	..	$2.88
Excavation	0.14	1.53	053	2.20	Cu. yd	316
Forms		014	0.10	024	Sq ft	0.39
Reinforcing		018	153	171	Cwt	0.32
Concrete-					Cu yd	319
Working chamber	013	132	323	468		
1st-2nd-3rd Sections	0.13	023	2.29	265		
Shaft	013	023	313	3.49		
Overhead-equipment ets						225
Total						12.19
Total cost of Pier	$141260 63					

NOTES

Cutting edge laid	11-9-1915
Caisson sealed	6-21-1916
Total days sinking	187
Delays	134½
Actual days sinking	52½
Average per day	157 ft
Max per day	410 ft
Max immersion	110.2 ft.
Max air pressure	495 Lbs.
Pier completed	9-6-1916

MAXIMUM FOUNDATION LOADS

Direct Load	5 07
Horizontal Load	2.83
Total	790

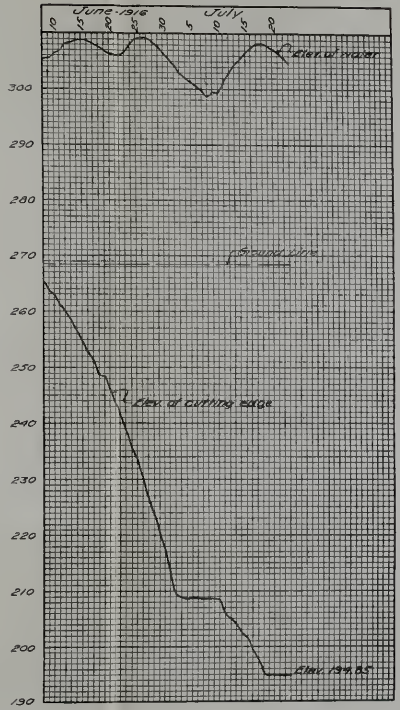
P.&I.R.R.
BRIDGE NO. L72 OVER OHIO RIVER
—AT—
METROPOLIS, ILL.
CONSTRUCTION RECORD
—OF—
PIER No. 3
Metropolis, Ill. July 1, 1917

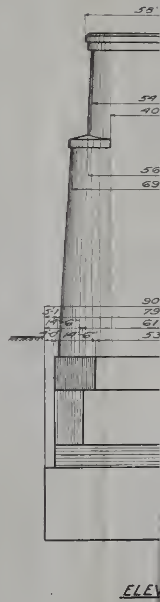
Fig. 21

SINKING DATA

Date	Elev. of Cutting Edge				Sinkage		Elev. of Ground				Water Stage		Depth Immersed	Weight of Caisson-Tons					Air Pressure			Reaction due to air pressure	Net Weight	Sq ft of friction surface	Tons per sq ft of friction surface	Material	Location	Remarks
	N.E.	N.W.	S.W.	S.E.	24 Hr.	Total	N.E.	N.W.	S.W.	S.E.	Gauge	Elev.		Timber	Conc.	Water and Earth	Misc.	Total	Gauge Plan	Gauge Cais.	Calc.							
June 8	266.38	265.92	266.02	264.46	0.0	3.20	268.3	268.7	269.6	266.9	21.1	305.3	40.1	627	6998		14	7639	18	18	17	6800	839	970	0.86	Sand-gravel	1.5"N. 2.5"W.	Air on 1:00 P.M. 7th
9	[illegible]	[illegible]	264.13	263.98	1.41	4.61	...	...	...	...	21.3	305.5	41.7	...	8578		..	9219	19	18	18	...	2419	1400	1.78	" "	" 9"W.	
10	[illegible]	[illegible]	263.63	[illegible]	0.85	5.46					22.0	306.2	43.3		10368	1573		12752	21	20	19	7560	3790	1650	3.13		2"N. 7.5"W.	
11	[illegible]	[illegible]	261.62	[illegible]	1.90	7.36					22.7	306.9	45.7		...	1789		12998	..	..	20	...	5436	2220	2.44		" 6"W.	
12	259.86	[illegible]	259.56	[illegible]	1.76	8.52					23.8	308.0	48.1			1939		13148	23	22	21	8320	4828	2580	1.87			
13	258.08	258.04	258.30	258.36	1.33	9.85					24.2	308.4	49.9		10964	2134		13735	23.5	..	22	...	5419	2970	1.83		1"N.	
14	256.36	[illegible]	256.45	256.80	1.84	11.69					24.6	308.8	52.1		11784	2343		14768	25	23	23	8700	6068	3530	1.72		.. 9"W.	
15	255.01	254.89	255.01	255.04	1.72	13.41					24.8	309.0	54.0		...	2612		15037	..	..	..	..	6337	4050	1.57		" 6"W.	
16	252.82	252.31	[illegible]	253.13	2.15	15.56					24.6	308.8	56.0			2787		15212	27	25	24	9450	5762	4700	1.22		0.5"N. ...	
17	251.32	250.24	251.22	252.21	1.59	17.15					24.0	308.2	57.0			2905		15330	28.5	26	25	9830	5500	5100	1.06		0 5.5"W.	
18	248.82	248.70	249.21	248.26	2.65	19.80					23.5	307.7	59.1		12362	3165		16168	29	27	26	10400	5768	5980	0.97		2"N. 6"E.	Location taken top of concrete.
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		..	3086		16093	28.5	26	25	9830	6259	6000	1.04	Sand-gravel-clay	1"N. 3"E.	" " "
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]			3285		[illegible]	30	28	26	10600	5683	6700	0.85	" " "	1"N. 5"E.	
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]			3486		[illegible]	30	..	..	...	5989	7300	.73			
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		12882	3774	34	17317	..	..	28	...	6717	8060	.83		2.5"N. 3"E.	
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		...	4130	..	17683	30	29	28	10350	6733	8650	.78		2.5"S. 4"E.	
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]			5040	..	18583	..	..	..	12700	6483	9400	.69		1.5"S. 0"	
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		13362	5559		19377	36	35.5	33	12630	[illegible]	9890	.70		1.5"S. 2.5"E.	
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		13704	6097		20412	38	35	34	13200	7212	10520	.69		0.5"S. 1"E.	
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		13938	6627		[illegible]	38	39	39	13800	7314	11200	.65		3.5"S. 2"E.	
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					24.4	308.6	85.3		14290	7074		22025	...	39	39	14700	7325	12070	.61		3.5"S.	
29	220.49	220.66	220.40	220.10	2.91	47.97					23.9	307.6	87.2		14706	7385	42	22760	41	39	39	...	8060	12620	.64		.. 4"E.	
30	217.57	217.57	217.37	217.30	2.94	50.91					22.4	306.6	89.1		...	7596	..	23071	42	..	..		8371	13220	.63		7"S. ..	
July 1	213.71	213.33	213.79	213.80	3.85	54.76					21.3	305.5	91.9			8822		24197	43	39.5	40	14900	9297	14000	.66		1.5"N. 1.5"W.	
2	209.12	209.35	209.56	209.21	4.33	59.09					20.0	304.2	94.9		15108	9462		25239	41.5	39	41	14700	10539	14850	.71		0 6"E.	
3	208.79	208.64	208.64	208.65	0.64	59.73					18.7	302.9	94.2		...	9366		25142	40	38	..	14350	10889	14970	.73		3"S. 2"E.	
4	208.76	208.62	208.65	208.58	0.02	59.75					17.8	302.0	93.4			9255		25128	43	38.5		14550	10578	14979	.71	Blue clay	3.5"S. 1"E.	
5	...	...	...	...	0.0	...					17.0	301.2	92.6			9154		25027	..	39	40	14700	10327	...	.69	" "	.. ..	
6	208.73	208.56	208.62		0.03	59.78					16.4	300.6	92.0			9103		24976	42	40	..	15100	9876	14980	.66		1.5"E.	
7	208.69	208.53	...		0.01	59.79					15.7	299.9	91.3			9014		24887	41	38		14350	10537	15000	.70		..	
8	208.67	208.44	208.55		0.03	59.82					15.1	299.3	90.7			9023		24896	..	..	39	...	10546	15010	...		3"S. 0"	
9	208.66	208.47	208.56	208.56	0.01	59.83					14.5	298.7	90.1			8947		24820	40	..	..		10470	15320			.. ..	
10	208.56	208.21	208.36	208.50	0.16	59.99					15.0	299.2	90.8			9048		24921	..	39		14700	10221	15040	.68			
11	206.52	205.82	203.55	206.02	2.43	62.42					16.6	300.8	94.8			9720		25593	43	41	41	15500	10093	15520	.65		12"S.	
12	205.07	205.11	205.08	204.83	0.96	63.38					18.5	302.7	97.7			10149		25926	42.5	..	42	...	10926	15560	.62		6"S. 2"E.	
13	204.10	204.38	204.47	203.83	0.81	64.19					20.0	304.2	100.0			10490		26267	42	40	43	15100	11167	15570	.71	Blue clay-sand	.. 8"E.	
14	202.80	202.48	202.63	202.42	1.63	65.82					21.1	305.3	102.7			10556		26733	41	38	44	14350	12383	15900	.78	" " "	2"E.	
15	201.93	201.44	201.50	201.78	0.92	66.74					22.2	306.4	104.7		15500	11266		27437	44.5	42	45	15880	11557	16170	.72		2"S. 3"W.	
16	199.20	199.33	199.18	198.91	2.43	69.17					23.1	307.3	108.1		...	11832		28001	..	..	47	...	12121	16600	.73			
17	197.03	196.57	196.74	196.77	2.45	71.62					23.9	308.1	111.3		15830	12439		28338	46	44	48	16600	12338	17000	...		4"S. 1.5"W.	
18	195.64	195.08	195.70	195.52	1.40	73.02					24.1	308.3	112.9		...	12747		29296	49	48	49	18140	11106	17270	.64	Sand	1"S. 4"W.	
19	195.19	194.71	194.88	194.88	0.48	73.50					23.7	307.9	113.0			12848		29347	51.5	51	..	19300	10047	17360	.58		3"S. 1.5"W.	Started sealing 12:15 A.M.
20	195.05	194.65	194.82	194.87	0.05	73.55					23.0	307.2	112.4						52	51.5	48	19480						
21	...	...	...	...	0.0	...					22.4	306.6	111.8						51.5	51	..	19300						
22	...	...	...	...							21.6	305.8	111.0						50	50		18900						Finished sealing 11:50 A.M.
23	...	...		...																								Air off 7:30 A.M.

DAILY PROGRESS PROFILE PLATE XII





Western Society of Engineers.
Vol. XXIV, No. 2, February, 1919.
Modjeski—Metropolis Bridge.

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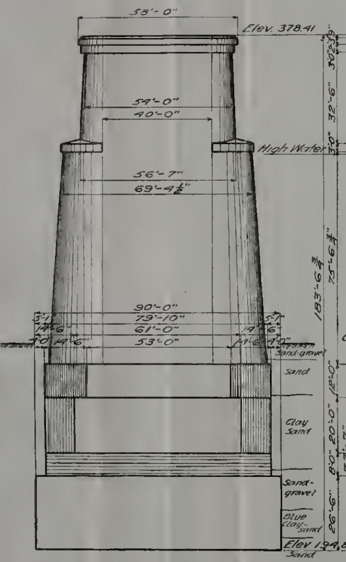
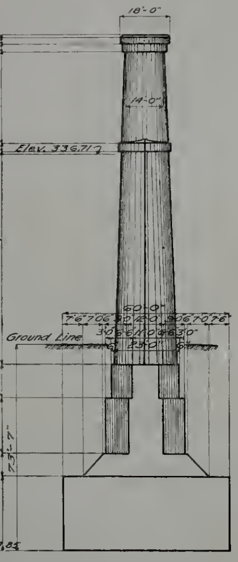


ELEVATION



END VIEW

QUANTITIES

Excavation		14672 Cu. yds.
Concrete :-		
1st Section	4213	
2nd Section	808	
3rd Section	1727	
Shaft	5684	
Total		12432 Cu. yds.
Timber-caisson and crib		423569 Ft. B.M.
Cement		18243 Bbls.
Corr. bars		210121 Lbs.

EXTRA WORK Included in above amounts.

Excavation	3107 Cu. yds.
Concrete	795 Cu. yds.
Cement	994 Bbls.
Corr Bars	8500 Lbs.

COSTS

	Overhead	Labor	Mat'l.	Total	Unit	Per cu. yd concrete
Framing-caisson and crib		28.50	42.11	70.61	M Ft. B.M.	
Pontoon				7.56	...	2.66
Excavation	0.14	1.65	0.51	2.30	Cu. yd.	2.71
Forms		0.12	0.09	0.21	Sq. ft.	0.33
Reinforcing		0.20	1.51	1.71	Cwt.	0.29
Concrete :-					Cu. yd	3.20
Working chamber	0.12	2.23	2.91	5.26		
1st 2nd 3rd Sections	0.13	0.22	2.34	2.69		
Shaft	0.12	0.36	3.01	3.27		
Overhead-equipment etc.						2.23
Total						11.42
Total cost of Pier	$142073.20					

NOTES

Cutting edge laid	1-4-1916
Caisson sealed	7-23-1916
Total days sinking	43
Delays	0
Actual days sinking	43
Average per day	1.68 ft.
Max per day	4.33 ft.
Max. immersion	113.2 ft.
Max air pressure	51.5 Lbs.
Pier completed	10-6-1916

MAXIMUM FOUNDATION LOADS

Direct Load	5.39
Horizontal Load	2.90
Total	8.29 Tons per sq. ft.

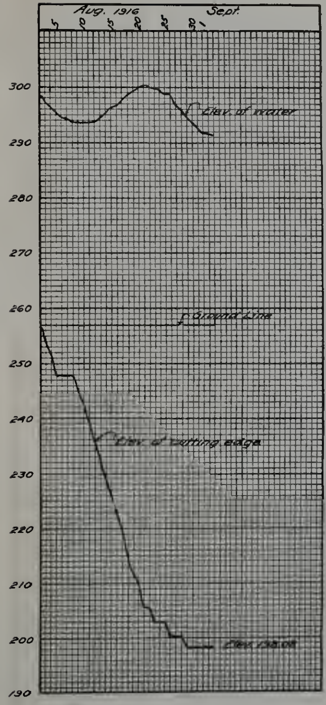
P.& I.R.R.
BRIDGE NO. 172 OVER OHIO RIVER
—AT—
METROPOLIS, ILL.
CONSTRUCTION RECORD
—OF—
PIER No. 4
Metropolis, Ill. July 1, 1917

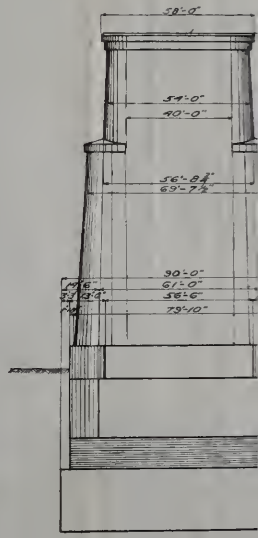
Fig. 22

SINKING DATA

Date	Elev. of Cutting Edge				Sinkage		Elev. of Ground				Water Stage		Depth Immersed	Weight of Caisson-Tons					Air Pressure			Reaction due to air pressure.	Net weight	Sq. ft. of friction surface	Tons per sq. ft. of friction surface.	Material	Location	Remarks
	N.E.	N.W.	S.W.	S.E.	24 Hr.	Total	N.E.	N.W.	S.W.	S.E.	Gauge	Elev.		Timber	Conc.	Water and Earth	Misc.	Total	Gauge Plant	Gauge Cais.	Calc.							
Aug. 2	255.32	257.44	257.14	255.33	0.54	0.54	257.2	258.2	258.4	254.0	13.9	298.1	41.6	820	6140		20	6980	22	18	18	6250	730	160	4.55	Sand·gravel	1"S. 20"W.	Air on 12.10 A.M. today.
3	252.97	252.53	252.75	254.90	2.67	3.21	...	...	...	...	12.9	297.1	43.3	...	7786		"	8626	22	19	19	6600	2026	970	2.10	" "	2.5"S. 10"W.	
4	252.50	250.36	250.79	252.02	2.52	5.73					12.0	296.2	44.9		9462	1696		11998	"	20	"	6940	5058	1730	2.92	Sand-clay	1"S. 16"W.	
5	247.92	248.03	248.04	247.55	3.37	9.10					11.1	295.3	47.9		10648	1938		13426		"		...	6486	2740	2.36	" "	" 13"W.	
6	...	...	...	...		...					10.3	294.5	46.6		...	1862		13350					6410	...	2.34			No sinking - placing shaft forms.
7											9.9	294.1	46.2			1824		13312					6372		2.32			" " " " "
8											9.5	293.7	45.8		11576	1786		13274	23				6334		2.29			Resumed work 8.00 A.M. to day.
9	244.57	244.44	244.61	244.47	3.38	12.48					9.3	293.5	49.0		...	2133		14549	25	22	21	7630	6919	3800	1.82	Clay·gravel	0" 2.5"W.	
10	242.58	242.02	242.19	242.41	2.22	14.70					...	...	51.2			2342		14758	"	"	22	"	7128	4900	1.62	" "	" 3.5"W.	
11	239.37	238.86	239.05	239.02	3.23	17.93							54.4		11922	2646		15408	26	23	23	7980	7928	5300	1.40		0.5"S. 4.5"W.	
12	235.70	235.14	235.39	235.52	3.63	21.56					9.4	293.6	58.2		12756	3105		16681	29.5	26	25	9020	7661	6500	1.18		3"N. 5"W.	
13	232.25	232.16	232.43	231.94	3.24	24.80					10.0	294.2	62.0		...	3466		17042	30	26.5	27	9200	7842	7300	1.05		2"N. 0"	
14	229.05	228.39	229.02	228.34	3.30	28.10					10.9	295.1	66.2			3866		17442	31	27.5	28	9540	7902	8800	0.90		0" "	
15	226.00	225.43	225.61	225.60	3.24	31.34					11.9	296.1	70.4		13340	4587		18767	33	30	30	10400	8367	9500	.88		1.5"N. 4.5"W.	
16	222.72	222.38	222.68	222.51	3.09	34.43					12.5	296.7	74.1		...	5024		19204	32	29	32	10050	9154	10400	..	Sand·gravel	2.5"N. 2.5"W.	
17	219.16	218.99	219.10	218.55	3.47	37.90					13.4	297.6	78.5		13916	5532		20288	35	32	34	11100	9188	11500	.80	" "	3"N. 3.5"W.	
18	214.19	213.74	213.95	213.86	5.18	43.08					14.3	298.5	84.6		14314	6350		21509	39	37	36	12800	8709	13000	.67			
19	211.99	211.45	211.66	211.75	2.21	45.29					14.9	299.1	87.4		14512	8000		23352	38	36	38	12500	10852	13700	.79	Clay-shale	3"N. 5"W.	
20	209.71	209.25	209.64	209.77	2.12	47.41					15.7	299.9	90.3		15036	8382	38	24276	37	35	39	12100	12176	14300	.85	" "	7"N. 4.5"W.	
21	205.63	205.34	205.51	205.21	4.12	51.53					15.9	300.1	94.6		...	8930	"	24824	41	38	41	13200	11624	15500	.75		1.5"S. 1"E.	
22	205.54	205.40	205.35	205.07	0.13	51.66					15.8	300.0	94.7		15580	...		25288	"	39	"	13500	11788	15600	.75	Clay	2"S. "	
23	203.08	202.83	202.89	202.84	2.42	54.08					15.5	299.7	96.8		...	9400		25838	39	36	42	12500	13338	16300	.82	"	0.5"S. 3"W.	
24	...	202.83	202.95	202.76	0.01	54.09					15.3	299.4	96.5			9362		25800	39.5	38.5	"	13300	12500	...	.77		" "	
25	203.10	202.77	203.00	202.66	0.03	54.12					14.5	298.7	95.8			9273		25711	41	38	41	13200	12511		..		1"N. 1.5"W.	
26	200.25	200.00	200.12	199.93	2.81	56.93					13.6	297.8	97.7			9528		25966	"	"	42	...	12766	17100	.74		2"N. 2"W.	
27	...	199.99	200.11	...	0.0	...					12.5	296.7	96.6			9401		25839	42	39	"	13500	12339	...	"		" "	
28		...	...								11.6	295.8	95.7			9275		25713	39	38	41	13200	12513		.76			
29	198.22	198.07	198.16	197.87	1.99	58.92					10.4	294.6	96.5			9173		25611	42	40	42	13880	11731	17800	.66		1"N. 1"W.	
30	...	...	...	...		...					9.3	293.5	95.4			9046		25484	45	43	41	14920	10564	...	.59		" "	
31											8.4	292.6	94.5			8926		25364	45	44	"	15270	10094		.57			
Sept. 1											7.6	291.8	93.7						"	45								Started sealing 4.15 A.M. to day.
2											7.4	291.6	93.5							"								
3											7.1	291.3	93.2															Finished sealing 2.45 P.M. Air off 3.25 P.M.

DAILY PROGRESS PROFILE PLATE XIII



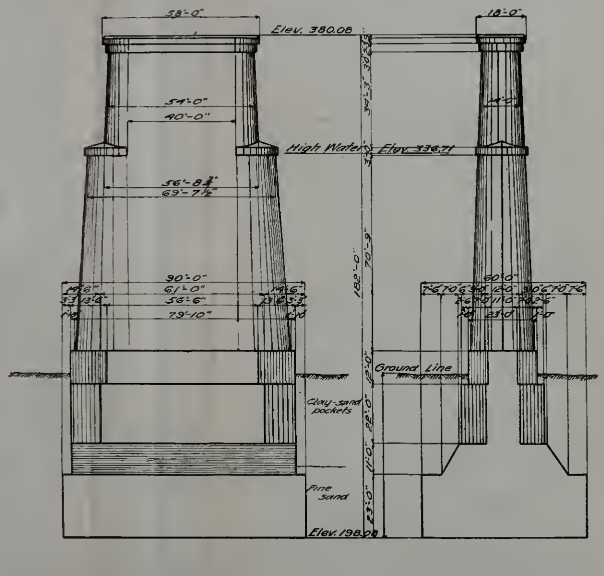


ELEVATION

Fig. 22

PLATE XIII

Western Society of Engineers.
Vol. XXIV, No. 2, February, 1919.
Modjeski—Metropolis Bridge.



ELEVATION

END VIEW

QUANTITIES

Excavation		11782 Cu.yds.
Concrete:-		
1st Section	3661	
2nd Section	1390	
3rd Section	1842	
Shaft	5624	
Total		12517 Cu.yds.
Timber-caisson and crib		415463 Ft B.M.
Cement		18493 B'bls.
Corr. bars		215185 Lbs.

EXTRA WORK - Included in above amounts

Excavation	2434 Cu.yds.
Concrete	845 Cu.yds.
Cement	1056 B'bls.
Corr. Bars	7000 Lbs.

COSTS

	Overhead	Labor	Mat'l.	Total	Unit	Per cu.yd. concrete
Framing-caisson and crib		35.15	42.70	77.85	M.Ft.B.M.	$
Pontoon				7.91	...	2.89
Excavation	0.15	1.48	0.61	2.24	Cu yd	2.11
Forms		0.08	0.09	0.17	Sq ft.	0.28
Reinforcing		0.31	1.53	1.84	Cwt.	0.32
Concrete:-					Cu.yd	3.19
Working chamber	0.13	2.31	3.04	5.48		
1st 2nd 3rd Sections	0.13	0.22	2.24	2.59		
Shaft	0.13	0.28	3.02	3.43		
Overhead-equipment etc.						$2.21
Total						10.95
Total cost of Pier	$137209.63					

NOTES

Cutting edge laid	5-10-1916
Caisson sealed	9-3-1916
Total days sinking	30
Delays	3
Actual days sinking	27
Average per day	2.15 ft.
Max. per day	5.18 ft.
Max. immersion	97.7 ft.
Max. air pressure	45 Lbs.
Pier completed	10-30-1916

MAXIMUM FOUNDATION LOADS

Direct Load 5.24
Horizontal Load 2.87
Total 8.11 Tons per sq. ft.

P.& I. R.R.
BRIDGE NO. 172 OVER OHIO RIVER
—AT—
METROPOLIS, ILL.
CONSTRUCTION RECORD
—OF—
PIER No. 5
Metropolis, Ill. July 1, 1917

Carbon Steel, one of each of Mayari Steel, one of each of Chrome Steel, and one of each of Silicon Steel. The High Carbon Steel contained from .28 to .37 of Carbon, from .30 to .64 of Manganese. Mayari Steel has been used by the writer in the Harahan Bridge at Memphis for all truss members, where economy of weight was desired. It has proved a very satisfactory material. In these tests, its composition was, Carbon .31 to .36, Manganese .61 to .76, Nickel 1.11 to 1.13, Chrome .47 to .57. The contents of the Chrome Steel were, Carbon .31, Manganese .49, Silicon .128, and Chrome .66. This steel was proposed by the manufacturers, but not seriously considered.

Silicon Steel had not been used in heavy bridge construction previous to the time these tests were made, and was therefore approached with caution. In these tests, it contained .35 of Carbon, .83 of Manganese, and .38 of Silicon. It will be observed that Mayari Steel gave the highest results and High Carbon Steel the lowest. Silicon Steel was finally selected as presenting the greatest advantages when both quality and price of this material came to be considered. The principal results of the column tests are shown in the following table in a convenient form:

	Specimen Tests Yield pt.	$\frac{1}{r}$	Breaking Unit Load lbs. per sq. in.
High Carbon	47,900	34.5 / 43.3	41,700
High Carbon	42,700	36.3 / 38.4	46,500
High Carbon	40,700	34.5 / 43.5	38,400
High Carbon	44,110	36.4 / 38.6	45,300
Mayari Steel	59,890	34.5 / 43.5	61,500
Mayari Steel	62,110	36.4 / 38.6	64,700
Chrome Steel	55,800	34.5 / 43.3	49,200
Chrome Steel	54,200	36.3 / 38.4	51,800
Silicon Steel	57,700	34.5 / 43.3	52,800
Silicon Steel	56,500	36.3 / 38.4	51,700

It was agreed from the start that a pin-connected design for all river spans would be used. Both Mr. Cartlidge and the writer con-

sidered such a design as best suited for long spans. It has the advantage of economy of material and rapidity of erection, two very important factors in the case of this structure. After all, an eye-bar, when made of good material, is the best and the most reliable part of the truss. Full-sized eye-bar tests have been made by the thousand and facilities for making them are available. It is the most simple tension member which could be designed. Very few riveted tension members have been tested and there always exists a doubt as to how a given riveted tension member would

Fig. 32. 550-Foot Spans During Erection

act if tested to destruction. While Silicon Steel was accepted for compression members of the Metropolis Bridge, it was decided to use either Nickel Steel or Mayari Steel for eye-bars. This, for the reason that Nickel Steel has been used in the Quebec, St. Louis Municipal, and other bridges, and Mayari in the Harahan Bridge at Memphis, and in all cases the tests have proved both these materials to be excellently suited for eye-bars of great strength. Silicon Steel was used in tension in the Metropolis Bridge, but only in the riveted end bottom chord sections, and certain riveted diagonals where reversal of stresses occurs. However, an allowance was made for it by reducing the unit stress below that which would be used for Nickel or Mayari Steel. Fig. 36 shows the excellent results obtained from the tests of full-sized Nickel Steel eye-bars for this bridge.

Extensive tests on Nickel Steel rivets made in connection with the Quebec Bridge proved that very little, if any, advantage could

be gained by their use; on the contrary, they are more difficult to drive and to cut out when defective. Carbon Steel rivets were therefore used throughout the work.

The floor system is of medium Carbon Steel. The lower unit stresses and thicker material used lend additional stiffness to the floor, besides rendering the effect of corrosion smaller in proportion to the thickness. The writer now believes that with the present experience with Silicon Steel, a further saving in weight might have been accomplished by making the panels longer and using Silicon

Fig. 33. Finished Bridge, End View

Steel for the floor system. The Thames River Bridge, now being built in New London, Connecticut, for the New York, New Haven and Hartford Railroad, will be entirely of Silicon Steel, including the floor system.

In the McKinley Bridge at St. Louis, and the Harahan Bridge at Memphis, the writer has used a loading, corresponding to present conditions, and also applied what he called a test load. In the former bridge, the test load consisted in increasing the working load by 50%. All members in which this test load gave unit stresses which exceeded the safe limits, were increased in section. In the latter, or the Harahan Bridge, the test load consisted of Cooper's E 75 loading, and the increase of section was made in a similar manner where necessary.

In the bridge under consideration, a high loading, corresponding to a test load, was adopted from the start, with correspondingly high unit stresses. This loading consisted of two Cooper's Loco-

motives E 90, followed by 7,500 lbs. per ft. of track. This is at least 30% more than the present heaviest traffic which the bridge will be called on to carry, but it does not mean that the bridge is designed for E 90 or even E 75 capacity, as usually understood, since the unit stresses are increased beyond those usually applied. It does mean, however, that the bridge is capable of carrying the loading of Cooper's E 90 with 7,500 lbs. per ft. of train load on both tracks without unduly overstressing a single member, and therefore with perfect safety. In other words, it would be unfair to compare this bridge with one calculated in the ordinary manner for E 60 loading, and say that the former has a capacity 50% greater than the latter. The method employed insures that, should such heavy loadings come upon the bridge, no member will be overstressed, while if figured in the usual manner some members, especially those near the middle of the span, might be stressed beyond safe limits.

Following is a list of principal unit stresses used in proportioning the superstructure:

Unit Stresses

	——Pounds per Square Inch——			
	Rivet	Silicon	Medium	Nickel
Tension on net section (members with alternate stress)		*30,000	.....	.....
Tension on net section		25,000	20,000	35,000
Compression—reduced by Gordon's formula		30,000	20,000	.....
Shear				
Webs, gross section		18,000	13,000	.....
Rivets, nominal diam	11,200	.....	.....	.....
Pins		.....	.....	20,000
Bearing				
Rivets, nominal diam	19,000	.....	.....	.....
Pins		30,000	20,000	35,000

Secondary stresses were carefully analyzed, especially in the 720′ span. As a result of this analysis, it was found desirable to counteract the secondary stresses in the end posts and stiff end chord sections of the 720′ span by applying to them a bending moment, opposite in effect from what it would be under dead and live load. This was accomplished by proportioning the lengths of the various members in such a way as to give the end post a deflection upward of 1⅛″ at M, and the stiff end bottom chord section a deflection upward of $\frac{11}{16}''$ at L_1. The negative moment thus produced was equal to the positive moment which would be expected from the full dead load and half live load. For full live load on

*Providing U. S. of 25,000 lbs. is not exceeded on total net area of member with the tension alone.

both tracks, there would be a small secondary positive moment applied to those two members which, however, would not cause stresses exceeding the permissible limits.

Several features of the design of the 720′ span are worthy of mention. All end posts, top chords and vertical posts were built of H sections, that is, with a continuous diaphragm connecting the two webs. There are no cover plates on the top chord or end posts, the intention being originally to provide special covers of comparatively thin plates, to keep out snow and cinders. It was finally decided to leave off these covers and drill holes in the diaphragms to provide drainage. The bottom chord eye-bars are in 72′ lengths, center to center of pins, corresponding to two panels; in other words, there

Fig. 34. Finished Bridge, Side View

is no pin connection at the sub-panel points. This was done for economy in the weight of material, since it saves one-half the weight of the eye-bar heads and of the pins. These eye-bars are 16″ wide, the thickest bearing being $1\frac{15}{16}$″ thick. They connect on 14″ diameter Nickel Steel pins. The end pins are 15″ in diameter. The end bearings are of a somewhat unusual size. The principle of their design is the same as that used by Geo. S. Morison a number of years ago in connection with the Bellefontaine Bridge near St. Louis. They are provided with a rocker joint, capable of rocking in two directions, parallel with and at right angles to the trusses. After the span was swung and equilibrium on the bearings established, wedges were inserted next to the rockers, so as to prevent any

further motion at right angles to the trusses, leaving, however, the motion parallel with the trusses unhampered. The object of the wedges is to add to the lateral rigidity of the end floor beams and end posts.

There being four lines of stringers, the two inside lines have been provided with stringer lateral bracing, the outside lines being attached to the inside ones by transverse angles. This arrangement is more economical than the usual one of two independent systems of stringer lateral bracing.

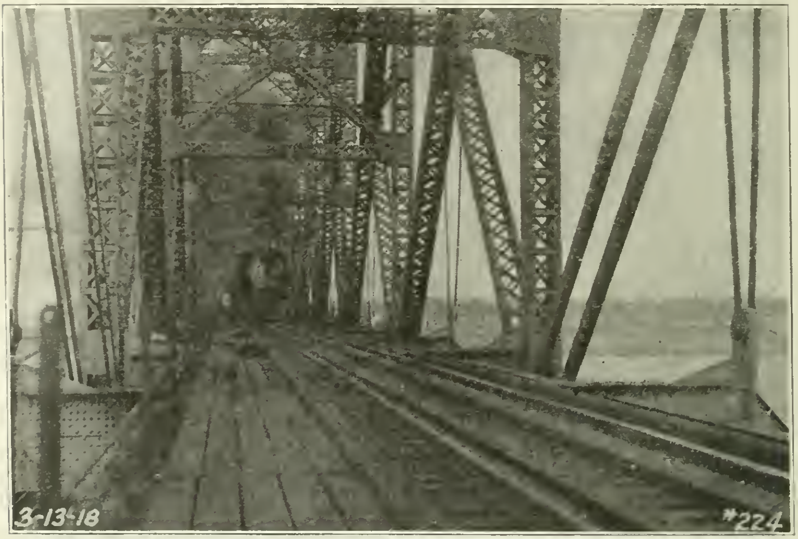


Fig. 35. Finished Bridge, Inside View

The weight of steel in the bridge is divided as follows:

North Approach	3,170,060 lbs.
One 300′ Span	1,670,245 lbs.
Four 550′ Spans (4,566,944 lbs. each)	18,267,776 lbs.
One 720′ Span	8,023,499 lbs.
One 246′ Span	1,159,806 lbs.
South Approach	1,387,490 lbs.
Total	33,678,826 lbs.

The weight of steel in the 720′ span, excluding the end bearings, is approximately 7,800,000 lbs., or 10,833 lbs. per foot of bridge.

The erection of this span, as well as of all other river spans, was performed by the derrick method, which has been recently used exclusively on large work. It has several advantages over the old traveler method, one of the principal ones being the saving of the additional width of falsework; another one being the saving of time required for the erection and rigging of the traveler. In case

of the span in question, it became necessary with the derrick method, to leave out portions of the sway system and top lateral bracing. In this, the fact that the vertical members had longitudinal diaphragms assisted considerably in making the structure safe during erection, before the top bracing was finally placed in position. The erection of this span proceeded very smoothly; the placing of falsework was begun on August 26th, 1916, and the span was swung on December 11th, 1916, the entire erection occupying 106 days.

The bridge was opened for traffic and the first train allowed to pass on December 15th, 1917.

Total quantities of materials in the main bridge and approaches are as follows:

Timber—Caisson and Pier Forms..	3,800,000 ft. B M
Concrete	93,382 cu. yds.
Corrugated Bars	2,063,000 lbs.
Cement	148,635 bbls.
Steel in Superstructure...........	33,693,516 lbs.
Creosoted Lumber in Deck.......	1,907,000 ft. B M
Steel in Pier and Pedestal Forms..	179,620 lbs.

The writer wishes to thank Mr. G. A. Haggander, Bridge Engineer of the Chicago, Burlington & Quincy Railroad, for his kind assistance in collecting and furnishing data for this paper.

DISCUSSION

The Chairman, G. A. Haggander, M. W. S. E.: Gentlemen, I think this bridge is a very distinct advance in bridge engineering. Two things have impressed me very greatly—one the length of time it took from the inception of the project until it was completed. It took nine years to start the bridge after it was first proposed and that shows how much time and attention must be given to these big things. That it pays to do this is shown by the smoothness with which the work went along after it was started. There was no hitch of any kind in it; it went right along in first-class shape.

The second thing that impressed me is the foresight and nerve, as you might call it, of the designers of this bridge in using the concrete piers for the first time in such a large scale and using the new steel,—the silicon steel,—and last of all in using the longest simple span ever built. I think they deserve a great deal of credit for those three things.

Albert Reichmann, M. W. S. E.: Some tests were made on compression members and some quite interesting points developed in these tests. I do not say these tests alone, but other compression tests showed that the strength of a compression member does not necessarily depend upon the amount of metal that is put into it; the degree of strength of the compression member depends on the detail of the member itself and the end connections. I am satisfied that a great many of our compression members would not render the service that is expected of them owing to the fact that the pin con-

nections are not always properly made and that sometimes the lattice bars are not developed to the extent that they should be.

One great feature of this bridge is that in the main compression members there was not so much expected of the lattice bars, more material being provided in two horizontal diaphragms, which made a more solid and compact compression member, thereby insuring the full strength of the material that is in the members.

I have observed in a great many cases where large members have been built for great compression that fork ends are used, and in cases of that kind it frequently happens the member is not sufficiently reinforced at the end to develop the full stress of the load into the member itself. That is a very important thing and I think that that point was pretty well brought out in recent tests on large compression members.

As Mr. Modjeski said, we have an abundance of tests on eye-bars and tension members, particularly eye-bars. The amount of information that we have on large compression members is still limited and I think that where large structures are built, whether they be buildings or whether they be bridges, it would be a good thing to provide an occasional test of compression members. I am satisfied that the compression member not only depends upon the construction of the member itself but also upon the component parts. There seems to be a tendency of late to use excessively heavy material in some of our large compression members, and it is perfectly proper to do so, providing the right quality of material is used, and if that is not the case, I think the tests made would show a very inferior member.

J. C. Blaycock, M. W. S. E.: The speaker has mentioned that the men were working under about four atmospheres. What death rate was experienced upon this bridge; what length of time was labor used under this extreme pressure and what difficulties were experienced in bringing the men to the surface? Also, what care and precautions were taken in selecting the riveting crews on these heavy compression members? It was my experience on this other bridge to find inexperienced men upon a high-class piece of workmanship. Did they have to take men who were not trained to assemble this piece of work which required so much study and minute detail? It has been my experience that the riveting crews in the field knew very little about the care with which such work should be handled. They will drill holes which do not match and use very little care. I note that care was used in the selection of the material for the rivets, but what precision and what care was used in the heating and in the driving?

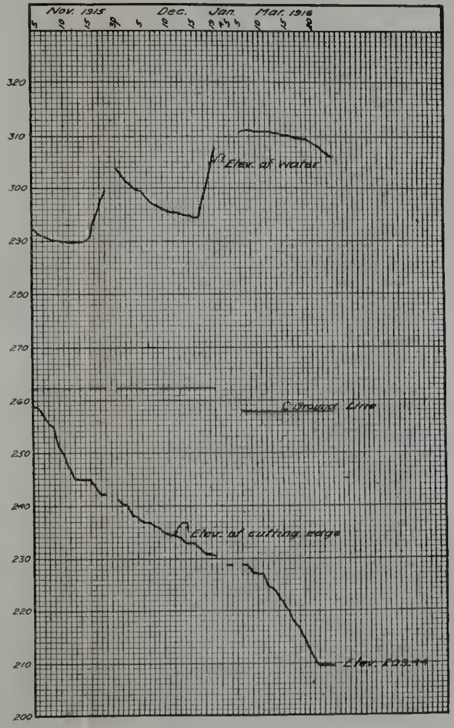
Mr. Modjeski: We had very strict rules about taking men out of the locks in not less than twenty minutes, and I think sometimes it took half an hour to lock out from the compressed air into the ordinary air. Besides that, we had a hospital lock where the men could be put under compressed air again and released gradually. This is the modern method of precaution.

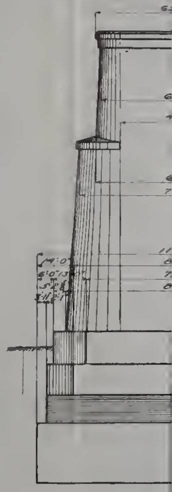
SINKING DATA

Date	Elev. of Cutting Edge N.E.	Elev. of Cutting Edge N.W.	Elev. of Cutting Edge S.W.	Elev. of Cutting Edge S.E.	Sinkage 24 Hr.	Sinkage Total	Penetration	Elev. of Ground N.E.	Elev. of Ground N.W.	Elev. of Ground S.W.	Elev. of Ground S.E.	Water Stage Gauge	Water Stage Elev.	Depth Immersed	Weight of Caisson-Tons. Timber	Conc.	Water and Earth	Misc.	Total	Air Pressure Gauge Man	Air Pressure Gauge Cais.	Air Pressure Calc.	Reaction due to air pressure	Net Weight	Sq. ft. of friction surface	Tons per sq. ft. of friction surface	Material	Location	Remarks
Nov. 4	25790	25870	25920	25860	0.30	3.70		2618	2614	2636	2622	7.9	292.1	33.3	1110	9952		44	11106								Mud		Air on 8.00 A.M. to day Men in 12.00 A.M.
5	25761	25861	25889	25826	0.26	3.96		"	"	"	"	7.2	291.4	33.1	"	11464		"	11638	16	15	14	6945	5693	1346	4.23	Fine sand	0" 0"	
6	25681	25631	25661	25751	1.52	5.48						6.7	290.9	34.1		13098			14642	"	"	15	...	8297	1863	4.45	" "	3"S. 1.5"E	
7	25536	25530	25492	25520	2.30	6.98						6.2	290.4	33.1		14098			15232					8307	2373	3.50		" "	
8	25480	25493	25398	25375	0.97	7.95						3.3	290.1	33.8		...	1257	48	16513	18		16		9378	2703	3.33		4.3"S. 1"E	
9	25134	25213	25070	24992	3.38	11.33						5.0	290.0	39.0			1316	"	16572	19		17		9627	3852	2.50		3"S. 4"E	
10	24961	24960	24936	24961	1.88	13.21						3.7	289.9	40.8			1500		16756	20	16	18	7400	9356	4491	2.08		0.5"N. 3"E	
11	24737	24828	24779	24707	2.41	15.62						3.6	289.8	43.1		14678	1737		17573	21	13	19	6945	10628	3300	2.01		2"S. 7"E	
12	24157	24633	24603	24347	1.79	17.31							...	44.9		15704	1948		18810	21	16	20	8333	10477	3319	1.77		1.5"S. "	
13	...	...	...	...										...		...	...		...	19	17	~	7870	10930	...	1.85		1"N. 2"E	Concreting 1st section of shaft.
14												3.7	289.9	45.0		16062			19168	20	18		8333	11835		2.00		" "	
15												6.3	290.7	45.8		16376	2026		19500	"	~		...	11767		1.83			No sinking - out of concrete gravel.
16	24240	24354	24122	24308	1.36	18.77						5.6	293.8	50.3		16609	2218		19980	22		22		11647	6371	1.83		1"S. 2.5"E	
17	24124	24215	24237	24131	1.34	20.11						12.7	296.9	54.7		...	2654	52	20920	22.5		24		12087	6837	1.77		1.5"S. 2.5"E	
18	...	...	...	...								13.1	299.3	57.1			2890	"	20656	22		23		12323	...	1.81		" "	No work done account rising water.
30	24099	24123	24153	24130	0.93	21.04						19.7	303.9	62.6	1110	18104	4269	60	23543	27	22	27	10190	13353	7153	1.87	Fine sand	1.5"S. 2.5"E	Men in at 8.00 A.M. yesterday.
Dec. 1	[illegible]	24010	24026	24021	1.00	22.04						18.3	302.5	62.2	...	...	4132	"	23406	29	24	..	11170	12286	7493	1.77		" "	
2	23990	24011	...	23973	0.83	[illegible]						17.0	301.2	61.2			4003		23279	28	20		9270	14009	7572	1.85			
3	[illegible]	23867	23852	23874	1.63	[illegible]						16.2	300.4	62.0			3956		23230	27	25		11580	11650	8126	1.94	Sand gravel	1"N. 1.5"E	
4	23830	23803	23761	23771	0.79	[illegible]						15.4	299.6	61.7			3946		23220	28	25		...	11640	8293	1.42	" "	2"N. 1"E	
5	23707	[illegible]	23670	23675	1.05	[illegible]						15.0	299.2	62.3			4054		23328	..	~			11648	8630	1.37	Sand-clay	3"N. "	
6	23703	[illegible]	[illegible]	23613	[illegible]	[illegible]						13.6	297.8	61.0			3917		23191	26	26	26	12050	11141	8660	1.31	" "		
7	23417	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						12.8	297.0	60.7			3315		22589	27.5	27	..	12510	10079	8692	1.16			
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						12.2	296.4	60.3			3291		22563	27	24		11170	11445	8822	1.30		3.5"N. 2"E	
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						11.8	296.0	61.1			3324		22598	29	26	27	12050	10548	9093	1.16		3.5"N. "	
10	23125	[illegible]	[illegible]	23121	[illegible]	[illegible]						11.4	[illegible]	61.8			...		...				...	...	9255	1.14		3"N. 1.5"E	
11	[illegible]	[illegible]	[illegible]	23153	[illegible]	[illegible]						11.1	295.3	61.1						26	23		11580	11018	9292	1.19		" "	
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						11.0	295.2	61.3			3690		22964	..	..		..	11384	9392	1.21		2"N.	
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						10.8	295.0	62.1			3730		23029	27	23		10665	12359	9647	1.28		"	
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						10.6	294.8	62.0			...		...	28	24		11170	11904	9123	1.23			
15	23257	23251	23243	23235	0.30	29.83						10.2	294.4	61.9						26	22		10190	12834	9787	1.32			
16	23137	23178	23130	23100	1.01	30.21						10.8	294.6	63.1			3693		23167	28	23		11580	11387	10080	1.07		4.5"S. 1"W	Location taken top of concrete.
17	23083	23047	23080	23102	0.62	31.37						14.7	298.9	68.1			4343		23617	29	26	29	12050	11567	10265	1.13	Sand-gravel	6"N. 3"W	
18	23067	23027	23063	23085	0.17	31.68						16.8	301.0	72.8			4866		24140	31	..	31	~	12090	10313	1.17	... clay	6.5"N. "	
19	23043	23008	23032	23062	0.24	31.92						23.7	307.3	77.5			6096		25370	35	33	34	16210	9160	10392	0.88	... ...	4"N. 4"W	Men out at 8.00 P.M.
Jan. 4	22881	22873	22870	22883	1.61	35.53						40.5	324.7	95.9															Cleaning out W.C. Air off last night.
5	...	...	..	..	0.0	...						41.1	325.3	56.3															No work done account high water.
Mar. 5	22881	22873	22870	22885	0.0	35.53	29.0	251.2	257.6	264.5	257.6	26.6	310.8	82.0	1110	19862	6205	60	27237	36	35	36	16210	11037	9557	1.12	Clay-gravel	2"S. 2.5"E	Air on 8.00 A.M. yesterday.
6	...	22830	22835	22871	0.33	35.36	.	"	"	"	"	26.5	311.1	82.3	...	...	6245	..	27277	..	34	..	15740	11537	9733	1.18	" "	" "	
7	22726	22702	22753	22727	1.45	35.03	30.5					27.0	311.2	83.9			6437		27489	37	35		16210	11289	10140	1.12		2"N. 2"E	
8												26.8	311.0				6897		27929				...	11729	...	..		" "	No location account storm.
9	22654	22637	22730	22712	0.78	35.31	30.8					26.7	310.5	83.9			...		...	37	36		16680	11249	10213	1.18	Clay-sand		
10	..	...	..	..	0.0	.	..					..	..	..						..	..		...	...	...	..	" "		
11	22524	22437	22437	22437	2.18	37.69	[illegible]							86.3			7338		28570			37		11830	10872	1.17		7"S. 4"W	
12	[illegible]	22402	22427	22416	0.38	[illegible]	[illegible]					26.6	310.8	86.6			7581		28613	38		38		11933	10966	1.08		5"S. "	
13	22183	22252	22241	22267	1.52	[illegible]	[illegible]					26.3	310.3	87.8			7899		28931	..	37	..	17130	11801	11470	1.03		2.5"N.	
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					26.7	310.7	89.1			8168		29200	38	36	39	16680	12520	11860	1.05		" 1"W	
15	21947	21962	21970	21942	[illegible]	[illegible]	[illegible]					25.9	310.1	90.4			8370		29402	39	38		17600	11802	12270	0.96			
16	21761	21764	21787	21749	[illegible]	[illegible]	[illegible]					25.8	310.0	92.4		20186	8842		30198	40	..	40	...	12598	12790	.98	Sand		
17	21630	21653	21657	21600	[illegible]	[illegible]	[illegible]					25.5	309.7	93.5		...	9001		30357	..	39	..	18050	12307	13180	.94	...	6.5"S. 1"W	
18	[illegible]	21472	21413	21436	[illegible]	[illegible]	[illegible]					..	..	95.3			9261		30617		.	41	...	12567	13640	.92		4.5"S. "	
19	21174	21183	21182	21210	2.01	[illegible]	[illegible]					25.2	305.4	97.0			9507		30863	41.5	40.5	42	18730	12133	14170	.85		2"S. 3.5"W	
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					24.7	[illegible]	98.1			10086		31379	42	41	.	19000	12379	14330	.86		7"S. 2.5"W	
21	20541	20482	20538	20565	[illegible]	[illegible]	[illegible]					23.0	[illegible]	98.6			10593		31949	.	.	43	...	12547	14820	.87		3"N. 2"E	
22	20534	20560	20536	20536	0.14	57.31	48.3					23.3	307.5	99.0			...		...	42.5	42.5	..	19700	12247	14850	.83		1"N. 1"E	Started sealing 2.00 A.M. to day.
23	..	..	..	..	0.0							22.5	306.7	97.2						.	"	42	...						
24	20533	20534	20541	20538	0.05	57.36	48.4					21.8	306.0	96.6															Finished sealing 8.00 A.M. to day.
25	..	...	..	..	0.0	...	..																						Air off 5.30 A.M. to day.

Fig. 23

DAILY PROGRESS PROFILE PLATE XIV

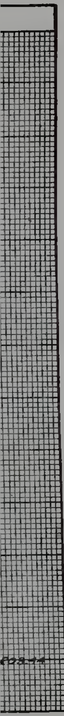


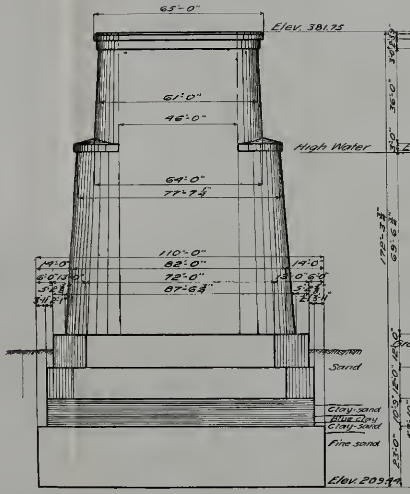


ELEV

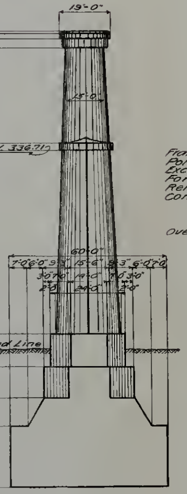
Fig. 23

PLATE XIV





ELEVATION



END VIEW

QUANTITIES

Excavation		12801 Cu yds
Concrete :-		
1st Section	4677	
2nd Section	1500	
3rd Section	2402	
Shaft	5601	
Total		14180 Cu yds
Timber-caisson and crib		766072 Ft B M
Cement		22616 B'bls
Corr Bars		236366 L'bs

COSTS

	Overhead	Labor	Mat'l.	Total	Unit	Per cu yd concrete
Framing-caisson and crib		24.20	37.22	61.42	M.Ft B M	
Pontoon				5.03	"	$3.59
Excavation	0.14	1.65	0.57	2.36	Cu yd	2.14
Forms		0.15	0.11	0.26	Sq ft.	0.35
Reinforcing		0.19	1.53	1.72	Cwt	0.28
Concrete :-					Cu yd.	3.40
Working chamber	0.13	1.86	3.41	5.40		
1st-2nd-3rd Sections	0.13	0.24	2.37	2.74		
Shaft	0.13	0.24	3.39	3.76		
Overhead-equipment etc.						2.35
Total						12.11
Total cost of Pier	$171695.97					

NOTES

Cutting edge laid	9-5-1915
Caisson sealed	3-24-1916
Total days sinking	138
Delays	89½
Actual days sinking	48½
Average per day	1.07 ft
Max per day	3.38 ft
Max immersion	98.6 ft
Max air pressure	42½ Lbs
Pier completed	5-26 1916

MAXIMUM FOUNDATION LOADS

Direct Load	4.77
Horizontal Load	1.82
Total	6.59 Tons per sq ft

P.& I.R.R.
BRIDGE NO. 172 OVER OHIO RIVER
AT
METROPOLIS, ILL.
CONSTRUCTION RECORD
OF
PIER NO. 6
Metropolis, Ill. July 1, 1917

SINKING DATA

Date	Elev. of Cutting Edge N.E.	Elev. of Cutting Edge N.W.	Elev. of Cutting Edge S.W.	Elev. of Cutting Edge S.E.	Sinkage 24 Hr.	Sinkage Total	Penetration	Elev. of Ground N.E.	Elev. of Ground N.W.	Elev. of Ground S.W.	Elev. of Ground S.E.	Water Stage Gauge	Water Stage Elev.	Depth Immersed	Weight of Caisson-Tons Timber	Conc.	Water and Earth	Misc.	Total	Air Pressure Gauge Plant	Gauge Cais.	Calc.	Reaction due to air pressure	Net Weight	Sq. ft. of friction surface	Tons per sq. ft. of friction surface	Material	Location	Remarks
Oct. 4	297.51	298.20	298.22	298.76	5.32	5.32		303.3	303.2	304.6	303.4	14.0	298.2																
5	297.52	297.26	297.35	297.00	1.00	6.32		"	"	"	"	15.3	299.5	2.2															
6	297.10	296.74	296.53	296.99	0.44	6.76						16.7	300.9	4.1	632	1332		35	1999	7	2	2	842	1157	2170	0.53	Sand	11"S. 1"E.	Air on 2.00 P.M. today
7	296.44	296.06	296.10	296.68	0.52	7.28						19.2	303.4	7.1	"	1788		"	2455	8	2	3	1263	1192	2340	.51	"	6.5"S. "	
8	296.42	295.98	296.09	296.66	0.03	7.31	8.5	300.7	302.3	308.0	308.0	21.5	305.7	9.4		"			"	11	5	4	1684	771	2350	.33		9.5"S.	
9	296.39	"	"	"	0.01	7.32	"	"	"	"	"	23.0	307.2	10.9						"	6	5	2105	350	2730	.13		10"S.	
10	293.15	293.60	293.20	292.89	3.07	10.39	11.6					23.2	307.4	14.2		2654			3321		"	6	"	801	3723	.22		"	
11	292.53	292.60	292.83	292.65	0.56	10.95	12.2					22.5	306.7	14.1		3440			4107	13	7	"	2950	1137	3900	.29		7"S. 1.5"E.	
12	292.32	292.45	292.70	292.37	0.22	11.17	11.9	299.5	302.4	306.7	308.4	21.0	305.2	12.8		3860			4527	"	"		"	1577	3810	.41		8"S. 1"E.	
13	290.23	290.22	290.20	290.23	2.20	13.37	14.1	"	"	"	"	19.3	303.5	13.3		4720			5387					2437	4520	.59	Clay	3.5"S. "	
14	286.78	286.81	287.63	287.58	3.03	16.40	16.4	300.0	301.4	306.2	306.6	17.6	301.8	14.6		5654			6321					3371	5300	.64	"	0.5"S. 1.5"E.	
15	286.18	286.49	287.27	286.94	0.48	16.88	16.9	"	"	"	"	16.0	300.2	13.5		6384			7031					4101	5450	.76		2.5"N. 1"E.	
16	283.04	282.37	285.64	285.76	2.52	19.40	19.4					14.2	298.4	14.2		"			"						6240	.66		6"N. 2.5"E.	
17	282.36	282.36	284.72	284.67	0.67	20.07	20.8	300.4	302.4	306.7	307.7	12.9	297.1	13.6							8		3370	3681	6480	.57	Sand	3"N. 1"E.	
18	281.14	281.23	282.86	282.73	1.59	21.61	22.3	"	"	"	"	11.9	296.1	14.1							"		"	"	6990	.53	"	8"N. 1.5"E.	Finished concreting 1st section
19	279.83	279.68	282.66	282.75	0.75	22.36	"	300.6	300.6	305.4	307.2	11.0	295.2	14.0	769	6442		39	7250	14	8.5		3580	3670	7350	.50		6.5"N. 1"E.	
20	276.07	275.89	279.36	279.53	3.53	25.89	25.8					10.4	294.6	16.9	"	7556		"	8369	16	11	7	4630	3734	8240	.45		6"N. "	
21	275.99	275.82	279.03	279.18	0.21	26.10	26.0					9.6	293.8	16.3		"			"	"	"	"	"	"	8300	"		6.5"N.	
22	271.49	271.69	275.47	275.26	4.02	30.12	30.0					9.3	293.5	19.9								9			9460	.40		3"N. 0"	
23	271.46	271.64	275.41	275.22	0.05	30.17	30.1					9.0	293.2	19.8		8160			8968		3	"	3780	5188	9480	.55		"	
24	269.51	270.19	274.09	273.44	1.69	31.81	31.7					9.9	294.1	22.3		9782			10590	17	11	10	4630	6810	9970	.69		1.5"N.	
25	267.38	268.26	270.88	270.50	2.41	34.22	34.1					10.8	295.0	23.6		"	376		10966	1	12	11	3060	5906	10650	.56		0.5"N.	
26	"	268.23	270.81	270.45	0.04	34.26	34.8	300.5	301.2	306.5	308.0	11.0	295.2	25.9		10592	"		11776			"	"	6716	10660	.67	Clay-sand	"	
27	266.44	266.22	267.84	268.06	2.20	36.46	37.0	"	"	"	"	11.1	295.3	28.2		"			"	18	12.5	12	5270	6306	11300	.58	" "	1"N. 1"E.	
28	264.61	264.68	265.99	265.92	1.84	38.30	38.8					10.8	295.0	29.7			678		12078	"	"	13	"	6808	11710	"		" 0.5E.	
29	"	264.64	265.98	265.86	0.03	38.33	"					10.6	294.8	29.5			"		"		12	"	5060	7018	11715	.60	Clay	"	
30	263.34	263.42	265.05	264.85	1.11	39.44	39.9					10.4	294.6	30.4		10974	776		12558		"		"	7498	11955	.63	"	1.5"N. 0"	Finished concreting 2nd section
31	259.84	260.10	260.77	260.37	3.90	43.34	43.8					10.0	294.2	33.9	924	12410	1062	42	14438	19		15		9378	12820	.73		2"N. 1"W.	
Nov. 1	258.70	258.35	258.87	259.07	1.51	44.85	45.4					9.8	294.0	35.3	"	"	1182	46	14562	"		"		9502	13150	"		1"N. 0"	
2	258.68	258.26	258.81	259.05	0.04	44.89	"					9.3	293.5	34.8			"	"	"					"	13160	"		"	
3	258.43	257.99	258.59	258.88	0.23	45.12	45.6					8.6	292.8	34.3											13210	.72		1.5"N. 0.5"W.	
4	256.72	256.62	257.00	256.91	1.67	46.79	47.3					7.9	292.1	35.3			1690		15070	18	11		4630	10440	13580	.77		3"N. "	
5	254.86	254.57	254.95	255.08	1.93	48.74	49.2					7.2	291.4	36.5			1324		15304	19	9	16	3780	11524	14000	.82		2"N. 0"	
6	253.65	253.53	253.94	253.88	1.11	49.85	50.4					6.7	290.9	37.2			2118		15498	17	9.5	"	4000	11498	14240	.81		"	
7	253.60	253.48	253.78	253.67	0.12	49.97	50.5					6.2	290.4	36.8		12788	"		15876	"	10		4210	11666	14260	.79			
8	253.48	253.32	253.28	253.21	0.31	50.28	50.8					5.9	290.1	"		13382	2307		16659	18	12		5060	11599	14350	.77		2.5"N.	
9	252.11	252.01	251.94	251.92	1.33	51.61	52.4		301.5	307.0	308.5	5.8	290.0	38.0		14652	2461		18083	19	13		5480	12603	14640	"		"	
10	249.85	249.74	249.78	249.66	2.23	53.84	54.6		"	"	"	5.7	289.9	40.0		14746	2854	50	18574	20	14	17	5900	12674	15100	.83		3.5"N.	
11	249.03	248.88	248.94	249.02	0.78	54.62	55.4					5.6	289.8	40.8		"	2991	"	18711	19	13	18	5480	13231	15300	.86		3"N.	Finished concreting 3rd section
12	249.01	248.83	248.99	249.01	0.02	54.64	"					"	"	"			"		"	21	13	"	6320	12391	15310	.81		"	
13	247.90	247.83	247.87	247.90	1.03	55.73	56.5					"		41.9			3185		18905	"	"			12585	15550	"			
14	246.04	246.32	246.36	246.16	1.60	57.33	58.1					5.7	289.9	43.6			3467		19187	17	11.5	19	4830	14337	15900	.90			
15	244.81	244.87	245.06	244.96	1.37	58.70	59.9			308.0	309.0	6.5	290.7	45.8			3713		19433	19	13	20	5480	13953	16200	.86			
16	243.68	243.91	243.92	243.61	1.12	59.82	61.0			"	"	9.6	293.8	50.0			3912		19632	22	"	22	"	14152	16520	.85			
17	243.64	243.69	243.73	243.49	0.14	59.96	61.2					12.7	296.9	53.3		15688	3937		20599	23		23		15119	16940	.92			
18	242.04	242.05	242.20	241.96	1.58	61.54	62.7		-			15.1	299.3	57.2		16004	4165		21143	23.5	17.5	25	7370	13773	16700	.83			
19	240.56	240.59	241.23	240.88	1.09	62.58	63.8					17.9	302.1	64.1		16558	4348		21880	25	19	27	8000	13880	16880	.82		4.5"N.	
20	[illegible]	[illegible]	[illegible]	[illegible]	1.10	63.68	64.9					[illegible]	303.4	[illegible]		"	3208		22740	"	18	28	7380	13760	17060	.88		3.5"N. 1"E.	
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]			5469		23001	23	23	29	9700	13301	17070	.80		"	
22	[illegible]	[illegible]	[illegible]	[illegible]	0.09	63.77	65.0					[illegible]	[illegible]	[illegible]			6628		[illegible]		25	30	10510	13650	17080	"		"	
23	[illegible]		[illegible]	[illegible]	[illegible]							[illegible]	[illegible]	[illegible]		16874	6772	58	24628	30	26	"	10590	13688					
24	[illegible]	[illegible]	[illegible]	[illegible]	1.79	65.56	66.8					[illegible]	[illegible]	[illegible]		17208	7154	"	25344	29	23	37	10510	14834	17330	.85		6"N.	
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]		17864	7493		26239	27	23	32	9700	16539	17520	.94			
26	[illegible]	[illegible]	233.90	233.16	[illegible]	70.95	71.7					[illegible]	[illegible]	[illegible]						28	26	33	10990	15359	18220	.84		10.5"N. 1.5"E.	Location taken top of concrete.
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	73.8					[illegible]	[illegible]	[illegible]			7353		26399	25	27	34	11370	15029	18590	.81		3"N. 4.5"E.	" " " "
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74.7					[illegible]	[illegible]	[illegible]			7503		26349	27	22	"	9270	17079	18740	.91			
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]			7738		[illegible]					[illegible]	[illegible]	.90		3"S. 1.5"E.	
30	225.56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79.6					[illegible]	[illegible]	[illegible]			7984		26830	29	25		10570	16320	19350	.84	Clay-sand	7.5"N. 1"W.	
Dec. 1	222.49	222.67	222.29	221.71	3.68	81.09	82.3					18.3	[illegible]	80.0			8305		27731	30	26	35	10940	16211	20040	.81	Gravel-sand	3"S. 6.5"E.	
2	220.39	220.51	[illegible]	[illegible]	2.18	83.27	84.5					17.0	[illegible]	80.9			8545		27331	36	35	"	14720	12671	20400	.62	Clay-sand	1"N. 2"E.	
3	"	"	220.20	[illegible]	[illegible]	[illegible]						[illegible]	[illegible]	[illegible]			8437		27303	38	38		16000	11303	20420	.55	Sand	" "	Cleaning out
4	220.52			[illegible]	0.03	83.51						[illegible]	[illegible]	[illegible]			8363		27215	"	"		"	11215	20420	"	"		
5					0.0							[illegible]	[illegible]	[illegible]															Started sealing 8.30 P.M. yesterday.
6	220.51	220.50		219.88	0.02	83.33						[illegible]	[illegible]	[illegible]															
7	"	"		"								12.8	[illegible]	76.7						36	36	33							Finished sealing 2.00 P.M. today.

DAILY PROGRESS PROFILE

PLATE

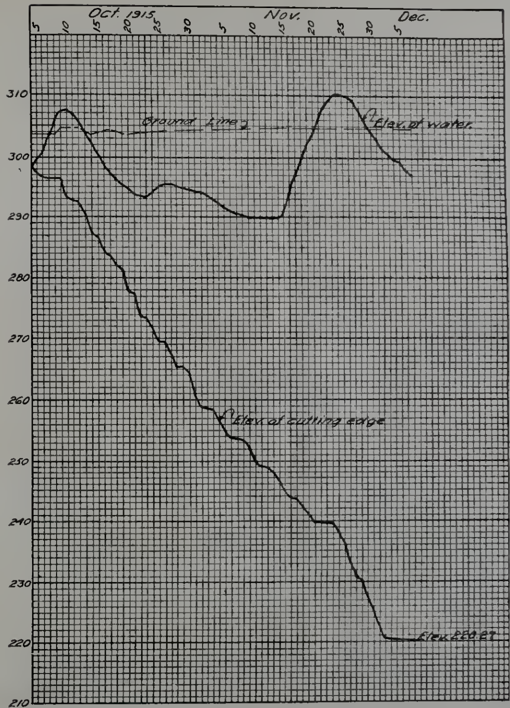


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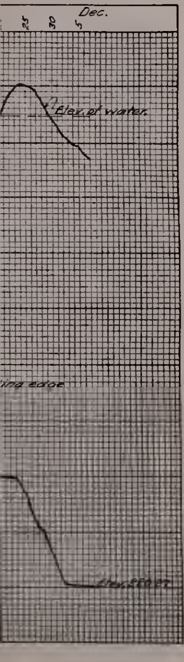
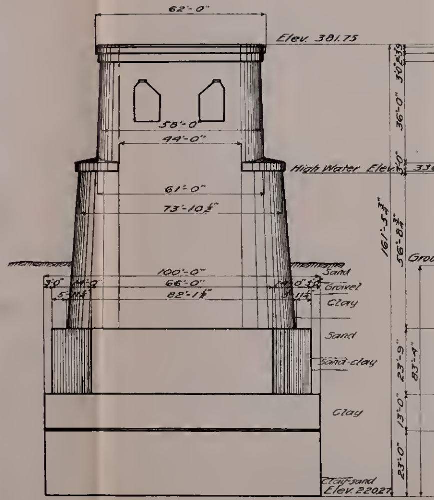
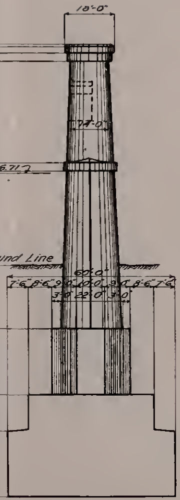
Fig. 24

PROFILE PLATE XV





ELEVATION



END VIEW

QUANTITIES

Excavation		18714 Cu. yds.
Concrete:-		
1st Section	4312	
2nd Section	1876	
3rd Section	1372	
Shaft	4285	
Total		11845 Cu. yds.
Timber-caisson and crib		442923 Ft. B.M.
Cement		19868 B'bls.
Corr. bars		233638 L'bs.

COSTS

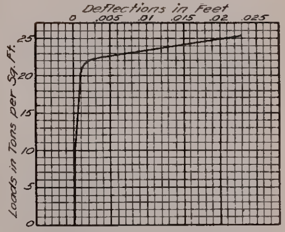
	Overhead	Labor	Mat'l.	Total	Unit	Per cu. yd. concrete
Framing-caisson and crib		28.15	42.20	70.35	M.Ft.B.M.	$2.63
Excavation	0.14	1.26	0.38	1.78	Cu. yd.	2.61
Forms		0.16	0.11	0.27	Sq. ft.	0.39
Reinforcing		0.20	1.53	1.73	Cwt.	0.34
Concrete:-					Cu. yd.	3.49
Working chamber	0.14	1.27	3.51	4.92		
1st-2nd-3rd Sections	0.14	0.21	2.60	2.95		
Shaft	0.14	0.25	3.51	3.90		
Overhead-equipment etc.						2.30
Total						11.76
Total cost of Pier	$141630.51					

NOTES

Cutting edge laid	9-4-1915
Caisson sealed	12-7-1915
Total days sinking	63
Delays	0
Average per day	1.34 ft.
Max. per day	4.02 ft.
Max. immersion	80.9 ft.
Max air pressure	38 Lbs.
Pier completed	5-9-1916

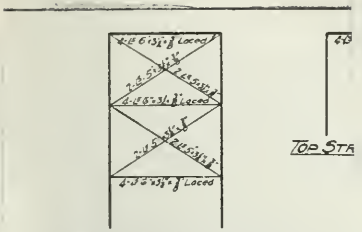
MAXIMUM FOUNDATION LOADS

Direct Load	4.76 Tons per sq. ft.
Horizontal Load	0.75 Tons per sq. ft.
Total	5.51 Tons

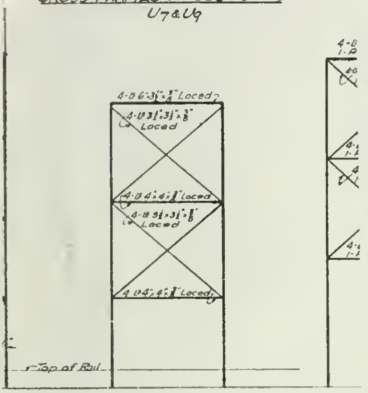


AVERAGE CURVE—BEARING TESTS
Tests made with Hydraulic Jack on sand at Final Cutting Edge Elevation

P.&I.R.R.
BRIDGE NO. 172 OVER OHIO RIVER
AT
METROPOLIS, ILL.
CONSTRUCTION RECORD
OF
PIER No. 7
Metropolis, Ill. Nov. 1, 1917



CROSS FRAMES AT SUB-POINTS
U7 & U9



5-8 & 10 CROSS FRAME-4 POR

-NOTES ON MATERIAL-

All main members except eye bars and U10-L10
All sub-diagonals, sub-posts and U10-L10 to be of Mediu
Eye bars to be of Nickel Steel, Pins of Nickel Stee
Floor and Bracing to be of Medium Steel
Static Load - Steel = 10700# per Lin Ft of Span
2-Decks = 1000# " " " "
Total = 11700# " " " "
= {95.4 kips per panel per Truss on Top Chord
{121.5 kips " " " Bott Chord

LIVE LOAD

Members
-2-E9 Engines followed by 7500# per Lin Ft
& 7500# per Lin Ft
Truss Members and Floor
ines followed by 7500# per lin ft on both Tracks

Im

On Chords & End
On Main Web Memb
On Secondary Truss
50% of the L.L. S
On Stringers - 5

DESIGNATION

"D" denotes Dead Load Stresses
"L" " Live "
"I" " Stresses due to Impact
"Wh" and "Wo" denote Wind Stresses horizontal and vertical respectively.
Stresses given in thousands of pounds (kips)
"+" denotes Tension "−" denotes Compression
{Bending Stresses given in Inch Kips.
{WB = Wind Bending
{LB = Static "

P. & I.

BRIDGE OVER O
AT
METROPOLIS
STRESS S
FOR
720 FT. DOUBLE T

Made by ..... Traced by ...
Scale 20 ft = 1"
DRAWING Nº 21
Correct

...hief Engineer
...ting Engineer

Fig. 28

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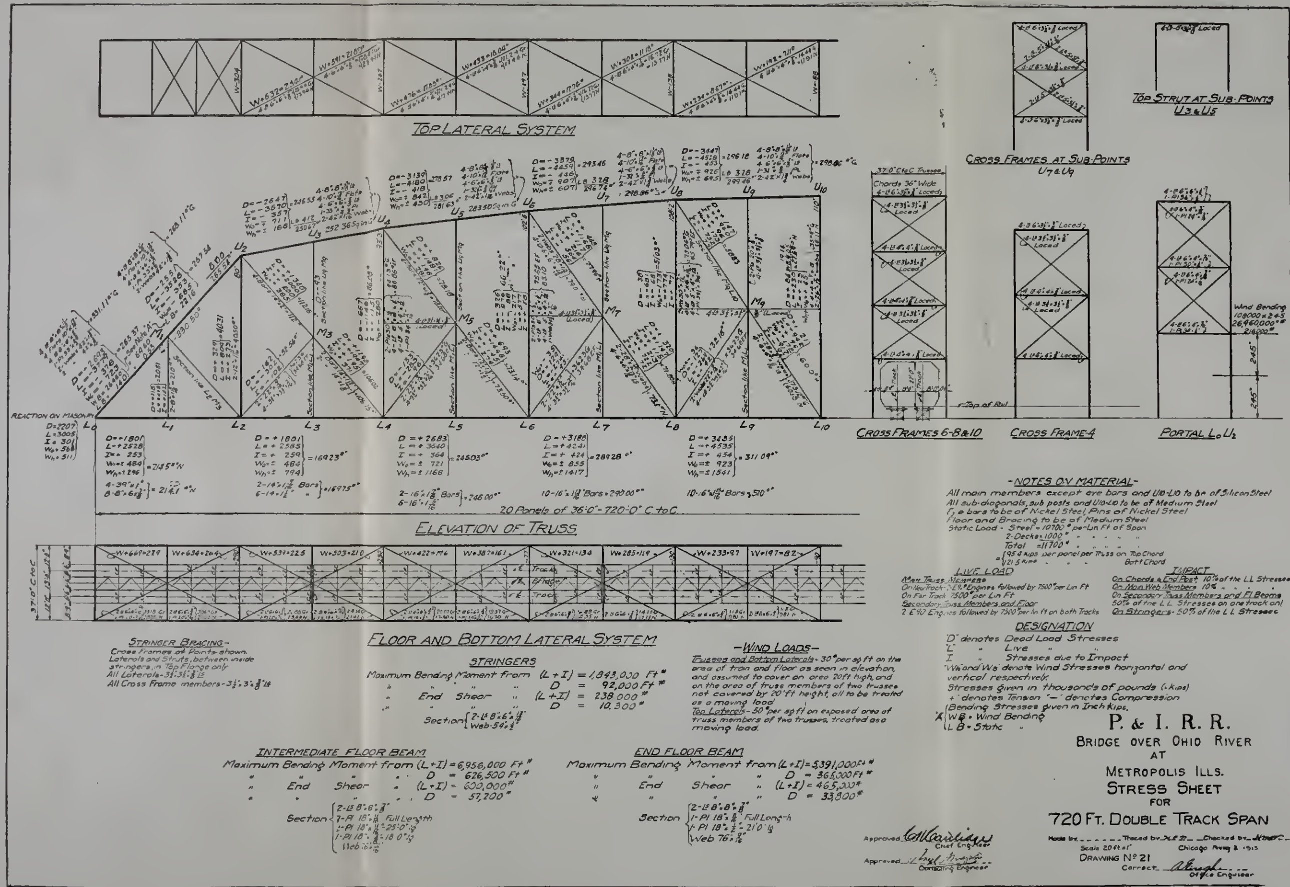


Fig. 29. Details of 720-Foot Span

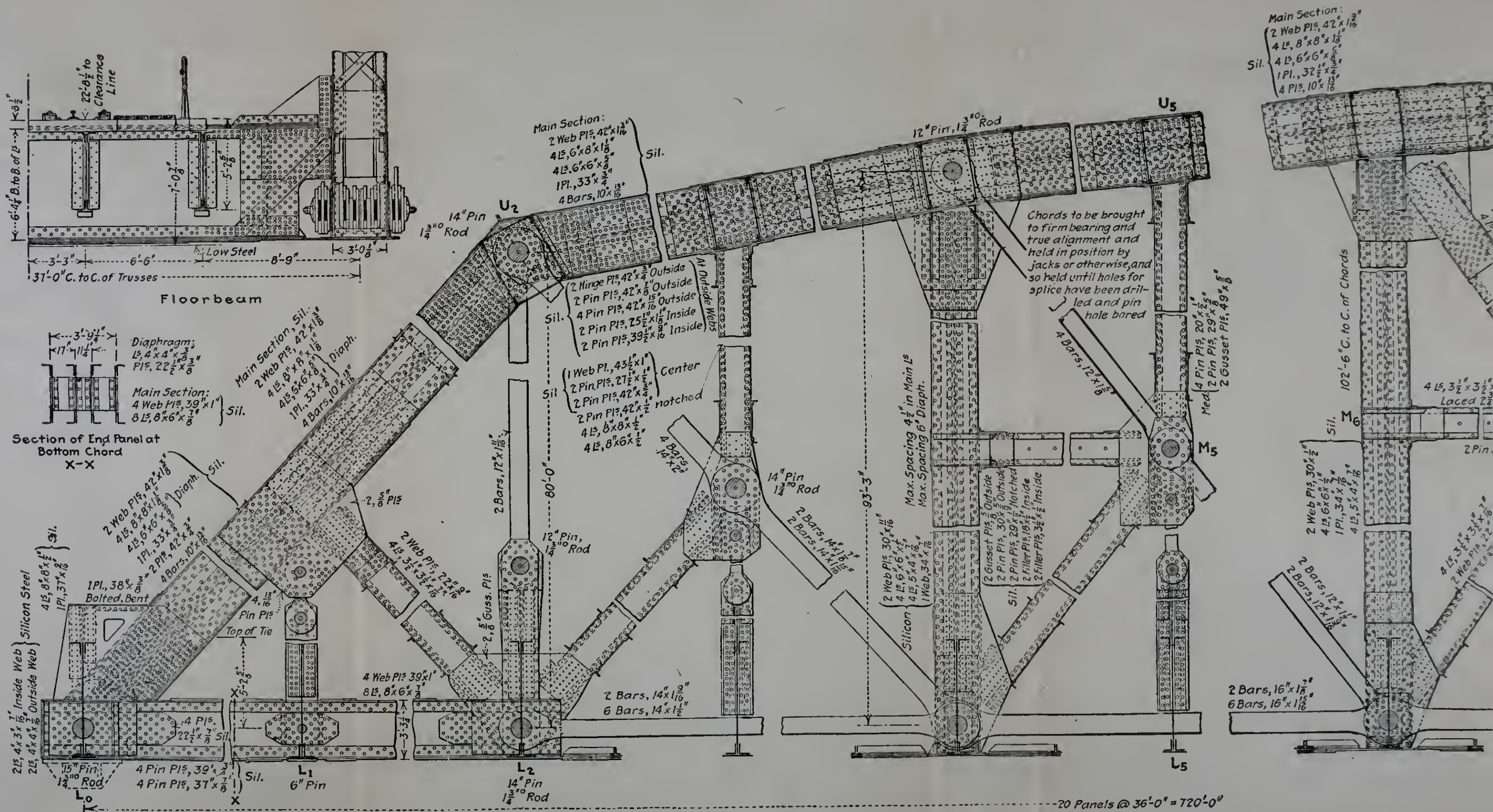
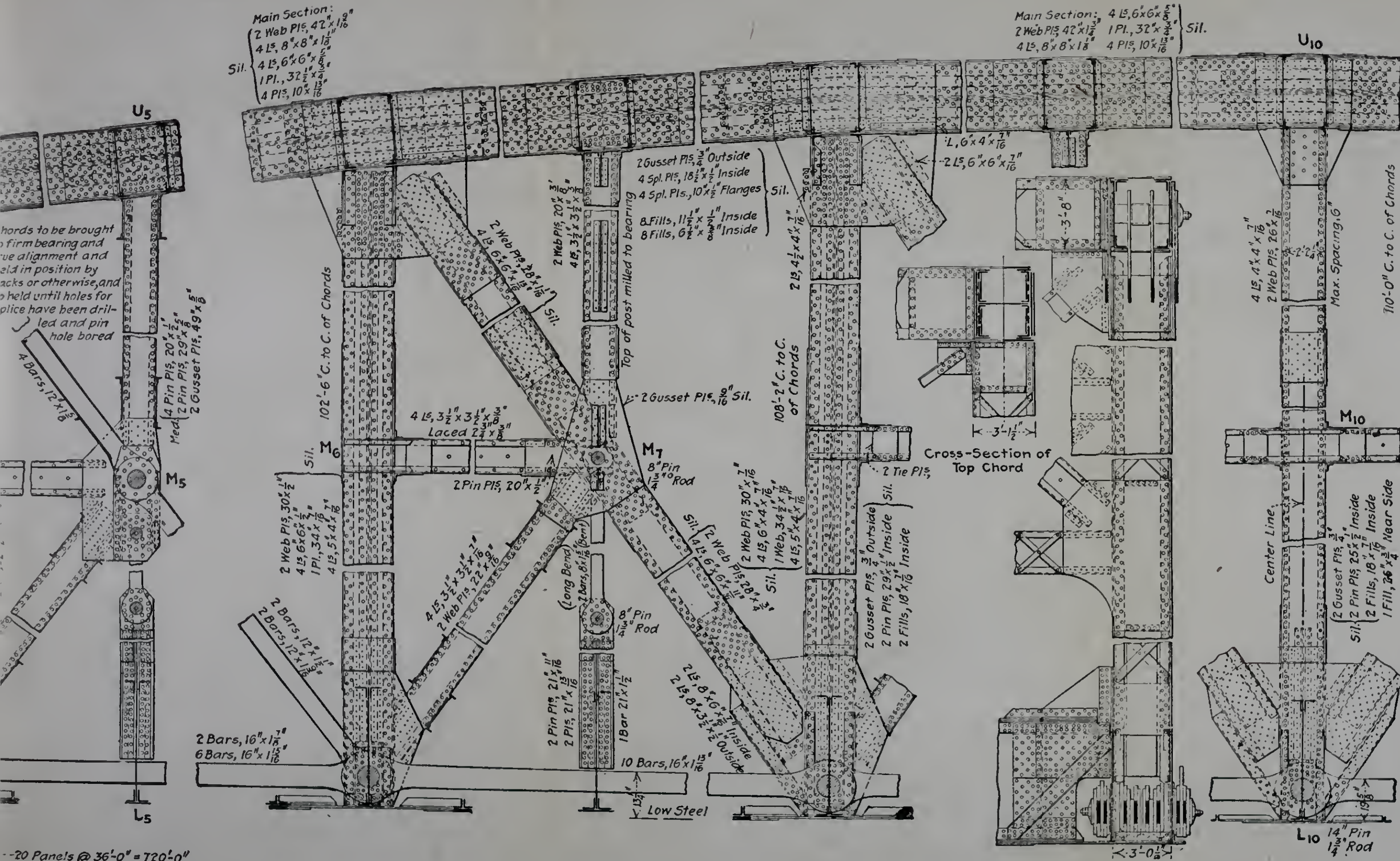


Fig. 29. Details of 720-Foot Span



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FROM SAME MELTS.

...TION ...EA ...NT	CHARACTER OF BREAK.
3	Cup
	Cup
	Cup
5	Cup
3	½ Cup
	½ Cup
	Cup
	Cup
	½ Cup
	½ Cup
	Cup
7	½ Cup
7	½ Cup
5	½ Cup
6	½ Cup
6	½ Cup
0	½ Cup
1	½ Cup
1	½ Cup
1	½ Cup
3	80% Gran.
2	½ Cup
3	½ Cup
2	½ Cup
7	½ Cup
3	Cup
5	Cup
1	¾ Cup
9	½ Cup
8	Cup
5	½ Cup
7	½ Cup
3	½ Cup
8	½ Cup
0	Irr.
8	Cup
7	Cup
3	½ Cup
5	Cup
6	50% Gran.
1	7/8 Cup
6	Cup
5	Irr.
0	Cup
3	½ Cup
0	½ Cup
2	½ Cup
7	¾ Cup
8	60% Gran
2	20% Gran

Fig. 36

TESTS OF NICKEL STEEL EYE BARS.

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Span	Mark	Test No	Melt No	Tests on Full-Size Eye Bars — Dimensions — Original — Nominal — Width	Nominal — Thickness	Actual — Length c to c of Pin Holes	Actual — Width	Actual — Thickness	After Test — Length c to c of Pin Holes	After Test — Width	After Test — Thickness	Results of Mechanical Tests — Reduction of Area Per Cent	Elongation — Per Cent in 12"	Elongation — Feet / Per Cent	Elastic Limit Lbs per Sq In	Ultimate Strength Lbs per Sq In	Place of Fracture	Character of Break	Carbon	Phosphorus	Manganese	Sulphur	Silicon	Nickel	Tests on Sample Bars from Same Melts — Elastic Limit Lbs per Sq In	Ultimate Strength Lbs per Sq In	Elongation Per Cent in 8"	Reduction of Area Per Cent	Character of Break
	LO-L1	1026	23659	8"	1 1/8"	31.38'	8.12"	1.13"	35.63'	6.54"	0.72"	49.1	29.5	18'-15.0; 27'-14.4	62100	95570	Body	100% Silky, cup							65350	103300	15.5	52.3	Cup
246'0"	LO-L1	1027	23659	8"	1 1/8"	31.38'	8.12"	1.14"	35.01'	6.60"	0.72"	48.7	31.5	18'-13.6; 27'-12.3	58860	93950	"	100% Silky, cup							66750	104350	16.7	51.9	Cup
	L2-L3	1028	23660	8"	1 7/8"	31.36'	8.04"	1.88"	35.09'	6.52"	1.46"	37.0	29.2	18'-12.6; 27'-12.4	56540	88290	"	100% Silky, angular							68370	100995	18.0	54.1	Cup
	L2-L3	1029	23660	8"	1 7/8"	31.36'	8.06"	1.88"	35.61'	6.70"	1.50"	33.6	27.5	18'-10.0; 27'-14.3	56430	90100	"	100% Silky, cup							62420	96700	18.2	54.5	Cup
	L2 L3	1030	20678	10"	2"	34.14'	10.00"	2.00"	37.43'	8.40"	1.60"	32.8	24.67	18'-12.?; 29'-10.3	59500	94750	"	100% Silky, angular	.37	.018	.71	.035	.116	3.32	58080	110600	16.2	49.0	½ Cup
300'0"	L2-L3	1031	20679	10"	2"	34.12'	10.04"	2.00"	38.45'	8.06"	1.40"	43.7	30.8	18'-15.5; 29'-13.7	59260	95380	"	100% Silky, 50% cup, 50% angular	.38	.016	.63	.036	.088	3.43	59530	101200	17.5	49.1	½ Cup
	L4 L4	1032	20678	10"	1 7/8"	34.08'	10.00"	1.62"	37.37'	8.20"	1.00"	49.3	28.8	18'-11.2; 29'-10.0	60180	97220	"	100% Silky; reverse cup	.37	.018	.71	.035			58170	106600	16.2	49.3	Cup
	L4 L4	1033	20678	10"	1 7/8"	34.10'	10.06"	1.62"	38.07'	8.42"	1.16"	40.0	29.1	18'-14.1; 29'-12.5	60450	98160	"	100% Silky, angular	.37	.018	.71	.035	.116	3.32	58170	106600	16.2	49.3	Cup
	U2 M2	1034	20075	12"	1 7/8"	33.41'	12.14"	1.94"	37.05'	10.06"	1.50"	35.9	33.0	18'-13.8; 27'-11.9	59660	90870	"	100% Silky, cup	.38	.012	.60	.033	.092	3.28	56900	100700	18.2	31.3	½ Cup
	U4 M5	1035	20100	12"	1 5/8"	36.36'	12.14"	1.68"	40.21'	10.00"	1.22"	40.2	28.5	18'-19.1; 30'-11.4	57000	92640	"	100% Silky, cup	.34	.016	.60	.026	.080	3.27	63180	95700	17.0	34.3	½ Cup
	M5 L5	1036	11447	8"	1 5/16"	35.66'	8.08"	1.34"	40.20'	6.52"	0.84"	49.4	31.6	18'-15.3; 31'-13.4	58630	92330	"	100% Silky, reverse cup	.34	.014	.52	.039	.100	3.31	64330	102000	16.5	51.5	Cup
	M1 L1	1037	11447	8"	1 5/16"	27.40'	8.08"	1.34"	30.74'	6.64"	1.02"	37.4	30.3	18'-13.8; 23'-13.2	58630	91220	"	100% Silky, angular	.34	.014	.52	.039	.100	3.31					
		1038	11447	8"	1 5/16"	27.40'	8.04"	1.32"	30.41'	6.70"	0.92"	41.9	25.8	18'-13.8; 23'-11.3	61260	96150	"	100% Silky, cup	.34	.014	.52	.039	.100	3.31					
	M1 L1	1039	11447	8"	1 5/16"	27.40'	8.10"	1.32"	30.34'	6.60"	0.90"	44.4	30.6	18'-11.4; 23'-11.1	62670	98220	"	100% Silky, reversed cup	.34	.014	.52	.039	.100	3.31					
	M1 L1	1040	11447	8"	1 5/16"	27.43'	8.10"	1.32"	30.20'	6.72"	0.86"	45.9	23.3	18'-10.8; 23'-10.2	60800	95410	"	100% Silky, cup	.34	.014	.52	.039	.100	3.31					
	M3-L4	1041	20105	14"	1 7/8"	38.06'	14.06"	1.92"	42.11'	11.56"	1.38"	40.9	36.1	18'-13.8; 31'-11.3	56300	94260	"	95% Silky, 5% fine granular, full cup	.38	.019	.60	.032	.056	3.41	62460	108700	16.2	29.7	½ Cup
	L2-L4	1042	19172	14"	1 1/2"	38.14'	13.96"	1.54"	43.46'	11.76"	1.02"	44.1	35.3	18'-17.0; 31'-15.3	55550	88140	"	100% Silky, angular	.35	.010	.59	.035	.052	3.26	60540	99660	19.2	33.7	½ Cup
720'0"		1043	23576	8"	1 5/16"	35.97'	8.12"	1.32"	41.07'	6.58"	1.04"	36.1	29.1	18'-16.1; 30'-15.0	59250	90950	"	100% Silky, angular	.34	.018	.59	.038	.140	3.29	59740	99710	17.5	49.5	½ Cup
	U2-M3	1044	20112	14"	2"		14.00"	2.06"		11.04"	1.50"	42.5	42.6	18'-16.6; 31'-13.3	64140	90430	"	100% Silky; angular	.38	.020	.62	.029	.068	3.39					
	U2-M3	1045	20103	14"	2"	38.05'	14.12"	2.04"	43.62'	11.70"	1.62"	34.2	35.3	18'-14.3; 31'-12.9	56420	91600	"	95% Silky, 5% fine granular, angular	.35	.018	.59	.031	.064	3.44	61180	98040	16.5	30.6	½ Cup
	M5-L6	1046	20081	12"	1 1/2"	38.30'	12.08"	1.52"	42.89'	9.86"	1.00"	46.2	29.1	18'-16.7; 31'-12.2	62090	95320	Head	100% Silky; full cup	.37	.011	.65	.029	.080	3.40	59230	101600	18.7	33.6	½ Cup
	L8-L10	1047	20076	16"	1 15/16"	36.34'	15.90"	2.00"	40.42'	13.22"	1.50"	37.6	35.5	18'-13.8; 29'-13.6	63990	93080	Body	100% Silky, full cup	.35	.018	.67	.031	.080	3.36	60000	103000	19.2	29.0	½ Cup
	L4-L6	1048	20080	16"	1 15/16"	36.12'	16.12"	2.00"	40.41'	13.18"	1.46"	40.3	38.6	18'-14.7; 29'-13.4	64200	94910	"	100% Silky, angular	.36	.010	.62	.030	.092	3.32	60100	102000	17.2	25.1	½ Cup
	L6 L8	1049	20101	16"	1 13/16"	36.54'	16.02"	1.86"	40.55'	15.80"	1.50"	30.5	27.0	18'-11.7; 29'-11.2	59230	95210	Head	100% Silky, angular	.36	.011	.54	.030	.068	3.39	61620	101400	18.0	32.1	½ Cup
	L4-L6	1050	20095	16"	1 15/16"	36.49'	16.06"	2.00"	41.76'	13.20"	1.50"	38.3	38.6	18'-18.0; 29'-16.4	55100	88100	Body	95% Silky, 5% fine granular, angular	.37	.017	.58	.033	.084	3.34	58580	95540	20.5	32.1	½ Cup
	L6-L8	1051	19154	16"	1 13/16"	36.25'	16.04"	1.86"	40.31'	13.14"	1.48"	34.8	32.5	18'-12.8; 29'-12.2	61510	95030	"	100% Silky, angular	.36	.015	.64	.032	.052	3.37	63180	103100	14.5	20.3	80% Gran
	U4-M5	1052	19155	10"	1 7/16"	40.77'	10.06"	1.44"	45.69'	8.14"	1.02"	42.7	31.6	18'-14.7	62110	93170	"	100% Silky, cup	.34	.013	.60	.034			61800	98400	15.7	45.2	½ Cup
	U4 M3	1053	23172	10"	1 3/8"	40.83'	10.12"	1.40"	45.65'	8.12"	0.94"	46.1	30.5	18'-15.5	56100	90820	"	95% Silky angular, 5% fine granular	.37	.017	.57	.027			64200	100800	17.5	51.3	½ Cup
	M2-U2	1054	23160	10"	1 7/8"	40.87'	10.06"	1.90"	45.19'	8.06"	1.24"	47.7	35.3	18'-12.0	60170	94710	"	90% Silky angular, 10% fine granular	.40	.012	.58	.027			63200	109000	14.7	32.2	½ Cup
	M2-U2	1055	19148	10"	1 7/8"	40.87'	10.04"	1.90"	45.10'	8.20"	1.44"	38.1	31.3	18'-13.8	63410	93550	"	100% Silky, angular	.38	.014	.60	.028			67400	109500	15.0	33.7	½ Cup
	L4 L6	1056	19521	12"	1 7/8"	39.46'	12.04"	1.92"	44.33'	9.84"	1.30"	44.6	35.7	18'-13.3	62280	92560	"	80% Silky cup, 20% fine granular	.39	.010	.62	.029		3.50	64250	106280	18.2	29.3	Cup
	L4 L6	1057	17253	12"	1 7/8"	39.42'	12.12"	1.90"	43.69'	9.76"	1.24"	47.4	35.8	18'-12.8	64560	98220	"	100% Silky, half cup, half angular	.37	.010	.65	.028		3.25	58870	106200	27.5	29.5	Cup
	U2-M3	1058	20375	12"	1 9/16"	37.27'	12.12"	1.60"	41.84'	9.86"	1.16"	41.0	36.3	18'-14.7	61880	93600	"	100% Silky, angular	.38	.016	.56	.032		3.26	59600	98260	19.2	40.1	¾ Cup
	M3 L4	1059	20394	12"	1 1/2"	37.24'	12.10"	1.56"	41.72'	10.04"	1.12"	40.4	32.8	18'-14.8	64610	99310	"	90% Silky; 10% granular, angular	.39	.020	.58	.030		3.26	62180	100100	19.0	52.9	½ Cup
	M5-L6	1060	12444	7"	1 1/4"	27.17'	7.06"	1.26"	30.52'	5.60"	0.84"	47.2	30.0	18'-13.8	65730	96630	"	100% Silky, angular	.33	.023	.63	.034		3.50	66500	102000	17.7	60.8	Cup
	M7-L7	1061	23157	7"	1 1/4"	33.60'	7.08"	1.26"	38.35'	5.74"	0.86"	44.6	25.0	18'-15.8	61090	90240	"	100% Silky; cup	.34	.019	.52	.035		3.26	60800	94540	18.7	50.5	½ Cup
	L6-L8	1062	20315	12"	1 11/16"	39.38'	12.10"	1.74"	44.28'	9.80"	1.20"	44.2	30.8	18'-15.0	62320	97150	"	80% Silky, cup, 20% sq granular	.37	.015	.61	.031		3.41	62540	100450	19.0	31.7	½ Cup
		1063	20319	12"	1 3/4"	39.39'	12.12"	1.80"	43.37'	9.80"	1.14"	48.8	34.6	18'-11.3	53850	90050	"	80% Silky, cup, 20% sq granular	.39	.023	.55	.035		3.33	61360	98440	17.5	31.5	½ Cup
	M3-L4	1064	20301	12"	1 7/16"	37.38'	12.06"	1.48"	41.95'	9.76"	1.02"	44.2	36.5	18'-15.1	63020	95240	"	100% Silky angular	.34	.030	.63	.033		3.32	61100	97900	18.7	30.8	½ Cup
	U2-M3	1065	19213	12"	1 9/16"	37.29'	12.06"	1.60"	42.02'	9.70"	1.14"	42.6	36.6	18'-15.0	54920	88080	"	95% Silky, 5% fine granular, angular	.36	.014	.56	.038		3.27	62880	97120	18.2	30.0	Irr.
551'3"	M9-L9	1066	24044	7"	1 1/4"	31.05'	7.08"	1.24"	34.02'	5.76"	0.82"	46.5	26.6	18'-10.5	71180	109990	"	100% Silky, cup	.37	.016	.53	.029		3.53	67000	102500	13.0	51.8	Cup
	M1-L1	1067	23079	7"	1 1/4"	20.36'	7.08"	1.26"	23.21'	5.64"	0.80"	49.4	27.8	16'-15.4	57170	91920	"	100% Silky; half cup	.36	.015	.57	.030		3.32	65200	100700	15.3	53.7	Cup
	M1-L1	1068	21731	7"	1 1/4"	20.32'	7.08"	1.24"	22.90'	5.70"	0.80"	48.1	29.6	16'-13.8	58650	91680	"	100% Silky, cup	.34	.019	.55	.035		3.33	64700	98500	13.0	57.5	½ Cup
	M3 L3	1069	20120	7"	1 1/4"	22.36'	7.06"	1.24"	24.90'	5.60"	0.82"	47.5	32.0	18'-12.2	64000	94850	"	95% Silky; cup, 5% fine granular	.34	.025	.59	.032		3.28	61480	99300	18.2	48.5	Cup
	L6-L8	1070	20302	12"	1 13/16"	39.54'	12.10"	1.86"	43.32'	9.86"	1.32"	42.1	33.3	18'-11.4	69080	101950	"	100% Silky, angular	.38	.018	.71	.035		3.50	66140	112210	16.5	27.6	50% Gran.
	L4-L6	1071	20307	12"	1 13/16"	39.43'	12.10"	1.84"	44.73'	9.62"	1.22"	47.2	32.6	18'-16.7	55480	92090	"	95% Silky, cup, 5% fine granular	.37	.018	.58	.033		3.35	62900	99360	16.5	31.1	7/8 Cup
	L2-L4	1072	20384	12"	1 5/16"	39.32'	12.08"	1.34"	44.30'	9.80"	0.82"	50.3	34.6	18'-15.6	60840	93880	"	100% Silky, cup	.36	.012	.53	.028		3.25	58180	96260	23.5	41.6	Cup
	L6-L8	1073	20313	12"	1 11/16"	35.64'	12.06"	1.72"	39.83'	9.64"	1.20"	44.2	38.8	18'-14.6	61480	93060	"	100% Silky, angular	.36	.010	.60	.030		3.54	60880	100950	19.5	29.5	Irr.
	L2-L4	1074	20393	12"	1 5/16"	35.52'	12.08"	1.38"	39.91'	9.90"	0.96"	43.0	34.1	18'-14.7	61490	95980	"	100% Silky, angular	.38	.021	.65	.034		3.70	60400	99000	19.2	35.0	Cup
	L8-L8	1075	20298	12"	1 13/16"	37.49'	12.10"	1.84"	42.42'	9.80"	1.30"	42.8	37.4	18'-16.6	58850	91410	"	100% Silky, angular	.36	.011	.60	.030		3.26	61960	96960	20.5	33.5	½ Cup
	L6 L8	1076	20372	12"	1 11/16"	37.88'	12.06"	1.72"	42.58'	9.78"	1.16"	45.3	34.2	18'-15.4	62190	96190	"	100% Silky, cup	.37	.020	.60	.032		3.36	60300	101000	21.2	33.0	½ Cup
	L2-L4	1077	20386	12"	1 5/16"	36.78'	12.10"	1.36"	40.67'	9.86"	1.16"	30.5	32.2	18'-12.8	61660	97200	"	100% Silky, angular	.34	.020	.65	.030		3.27	62260	103400	21.0	39.2	½ Cup
	L2 L4	1078	20379	12"	1 3/8"	36.71'	12.06"	1.36"	41.37'	9.70"	1.00"	40.8	35.3	18'-15.6	56700	91150	"	100% Silky, angular	.34	.012	.55	.035		3.33	58650	98900	20.5	34.7	¾ Cup
	L6-L8	1079	20374	12"	1 11/16"	37.71'	12.10"	1.74"	41.07'	10.06"	1.28"	38.8	27.0	18'-11.2	61040	99760	"	100% Silky, cup	.38	.012	.65	.033		3.50	62440	108500	15.0	26.8	60% Gran
	L6-L8	1080	17264	12"	1 13/16"	40.58'	12.10"	1.86"	44.75'	9.84"	1.34"	41.4	31.7	18'-13.2	60190	94400	Head	50% Silky, cup, 50% Silky, angular	.38	.010	.57	.094		3.38	62570	105250	17.7	28.2	20% Gran

As to riveting, there was the very best care used in selecting men. Nothing was neglected to make that a first-class piece of work. As to drilling holes, that was not necessary on work of this kind, because all the holes were drilled in the shop where the truss members were assembled. There were no mis-matched holes at all. As to heating rivets, I think perhaps the general foreman of the American Bridge Company can better advise as to how they were heated. Our inspector saw that when they got into the hole they were at the proper temperature.

K. L. Strickland: A special method was employed on all these big spans in obtaining the proper camber. Rails were cut up of the proper lengths and cribs were built at the proper elevations on which the spans were assembled. Instead of using the old method of ordinary wood the spans were brought to the proper elevation and steel shims used on top of the steel cribbing, when necessary, with the use of hydraulic jacks. When the spans were connected, the load was taken from the steel camber blocking, which was then removed, the jacks slacked down and the spans brought down gradually. There was none of the old method of splitting out blocking and allowing the spans to drop at will.

As to the riveting, the best men the bridge company had were selected for this work. They used what is known as a rivet pot, a cast iron pot of sufficient dimensions to take the length rivet required. Coke was used on those pots. It makes a perfectly clean rivet, the sulphur all being removed from the fire. What is known as No. 90 special hammer was used in the majority of the work.

Mr. Reichmann: In regard to riveting, Mr. Modjeski made reference to the fact that carbon steel rivets were used, not nickel. The experience with nickel rivets seems to be that if you use pressure on a nickel rivet, it takes so much pressure to drive a nickel rivet in that when the pressure is released the steel of the member frequently pushes out the head of the rivet again, and the only way to get a good nickel rivet is to come around and offset after it is cold, which is rather objectionable.

We had the same trouble on the St. Louis bridge, and after they had been driven, gave the rivet another set with the hammer after it had cooled. For that reason it is much better to use a carbon steel rivet; you get more satisfactory results.

G. M. Ilg, A. W.S. E.: What impact was used?

Mr. Modjeski: I can read the paragraph in the specifications which will answer the question:

"Impact. Approaches. Impact shall be provided for by addition of 22,500 pounds to each of four drivers on one rail of each track on the engine which will cause greatest stress.

"Trusses. Ten per cent to be added to the live load stress in chords and end posts and 10 per cent to web members on 720 and 551 spans, 20 per cent on web members on 300 and 245 spans except hangers and subdiagonals.

"Floor, hanger and subdiagonals, 10 per cent of the live load for one track to be added on the near track.

"Wind Trusses. Wind to be taken at 30 pounds per square foot on area of train and floors as seen in elevation and assumed to cover an area of 20 feet high, in addition to figure area of truss members for two trusses not covered by 20 feet height at 30 pounds per square foot, all to be treated as moving loads."

J. M. Pearl, M. W. S. E.: I note that considerable study was made in examining the form of truss in this particular case, according to the paper, and I would like to inquire why the panel point No. 2 near the end was carried to a height of 80 feet. Ordinarily you don't expect the most economical truss to be in a form where the top chord would follow approximately the parabola, and in many comparative designs that I have made I have found that by taking the first or second panel from the abutment or the end, and using a height only sufficient to get immobility, and starting from that, a straight line would come tangent to a circular curve on the top, giving more economical construction than could be obtained by an outline.

I also note one peculiarity in the top chord—about 300 square inches of section at the center with steel members that were testing about 60,000 pounds per square inch, in the lower chords the eyebars that tested to about 100,000 pounds per square inch of section and a center of 311 square inches. If the last limit was used as a basis of strength, of course you would come nearer a uniform section, but it occurs to me, without going through the complication, that the difference in the wind stresses in the top and the bottom chords would not make it necessary to put 311 square inches of section in the bottom chord and under 300 in the top one.

Mr. Schacher: In connection with our consideration tonight of the words "longest simple truss span" it is of interest to note that not a great distance from this bridge another bridge is now being erected containing the longest simple riveted truss span—a span of 639 feet. This is at Louisville. It is being placed there in connection with the reconstruction of the Pennsylvania Line's bridge over the Ohio River. Until the completion of this span the record span that is entirely riveted to the shift line chord is a 525-foot span belonging to the same company just over the Ohio a short distance from Pittsburgh.

O. F. Dalstrom, M. W. S. E.: The author stated that to begin with they were not satisfied that silicon steel would be a satisfactory material, but before the completion of the design they had adopted that for a part of the member—the compression member. Were any series of tests carried out to establish silicon steel as being the proper material?

Mr. Modjeski: We had quite a number of specimen tests of silicon steel and the object of making those compression tests was to establish the strength and quality of that silicon steel.

The Chairman: A book has just been issued by the Bureau of Standards giving the details of those tests on the silicon steel columns, and that is what the decision was based on.

Mr. Reichmann: Silicon steel was not a new steel, it had been used very extensively by the United States Government in its boat construction prior to the building of this bridge, so it really wasn't a new steel. It is steel that has been used for a great number of years. However, it has not been used in bridges, due to the fact that there was really no occasion for it up to the time we began to build the longer span bridges.

Mr. Pasalias: What was the cost of the bridge compete?

The Chairman: Approximately three million dollars. There is one thing I want to mention in this connection regarding the depth of these foundations. I think that is about the deepest foundation ever put down by the pneumatic process—the deepest I ever heard of.

Mr. Modjeski: I am not quite sure whether the Eads bridge was not a little deeper.

The Chairman: We were speaking about accidents in caissons. I believe that Mr. Cartlidge's death was largely caused by going down in these caissons frequently. He was not physically robust and he insisted on going down there; he wanted to see what was there. He thought that was his duty and he came out very much exhausted every time he went down. I think that is one of the things that caused his death. So this bridge is a memorial to him in a good many ways. Name plates have been put on each end of it with his name on them as a memorial.

Question: Why were elliptical sections chosen?

Mr. Modjeski: This is the usual form of pier recognized as producing the least disturbance in the current. We used a cross section of the river by the section of the piers, and if they were not properly constructed, the head that they would form by a reduction of the cross section of the river might create disturbances and might scour around the piers, so they were made pointed and circular in order to produce that effect for the defense of the head.

Wm. Artingstall, M. W. S. A.: In regard to the Chairman's remark, I think he is right in the depth of the caissons in this country but not in foreign countries. India in particular has some very, very deep caissons and some have gone one thousand one hundred and sixty-five feet. They have a kind of pneumatic process in a way, but still it isn't. They use a great deal of mechanical appliances for digging, and I was going to ask the question as to whether you used that or used manual labor and shot the material up through, or if you used just a plain hoist.

Mr. Modjeski: For excavating in sand and small gravels we invariably use what we call a pump or a blow-out, and for excavating clay we use the shafts, taking it out in buckets. As to the

object of pontoons, when we build caissons of these dimensions it is very unsafe to launch them. They have to be launched sidewise and they hit the water broadside and in many cases—in fact it happened on the McKinley Bridge at St. Louis, with which I was connected—we sprung the caisson quite badly in launching it. The method of pontoons is considered very much safer. We had no trouble whatever and have had none since that method was adopted.

L. W. Skov, A. W. S. E.: The pontoon was not always used. In some cases the caisson was towed out and the pontoon lovered at the time the caisson was built.

Mr. Modjeski: I just want to confirm what Mr. Reichmann said here and express my appreciation of the spirit in which the American Bridge Company conducted the work. It was really almost clockwork performance in its regularity and perfection. The Union Bridge Company developed a great deal of proficiency in that work and contributed a great deal toward the design of the intricate details of the plant, etc. The work was done on a cost and percentage basis and there was never any friction between contractors and the engineer, either on the sub-structure or superstructure.

CLOSURE

Mr. Modjeski: Referring further to Mr. Blaylock's questions, the writer finds that there were two deaths from compressed air on the Metropolis Bridge foundations.

The schedule of lengths of shifts in the air locks was as follows:

0′ to 45′	1-8	hour	shift	per day
45′ to 65′	2-3	"	"	"
65′ to 80′	2-2	"	"	"
80′ to 95′	2-1½	"	"	"
95′ to 110′	2-1	"	"	"
over 110′	2-40	min.	shift	per day

Mr. Pearl questions the form of the truss. It is true that a parabolic top chord coming down lower at the hips than in the design as executed, would have resulted in a slight economy of material. The importance of appearance, however, weighed in favor of the form which was adopted. Regarding the greater number of square inches of metal in the bottom chord than in the top chord, this is entirely due to the wind forces, which, in a span of such great length, are very large. The analysis of all the forces and sections are fully given on the appended stress sheets.

The chairman's remark that the foundation of pier No. IV was the deepest ever reached by pneumatic process is correct. Previous to this, the foundation of the east pier of the Eads Bridge at St. Louis was considered the deepest. The head of water at that foundation reached 110 feet 6 inches, or 2.7 feet less than at pier No. 4 of the Metropolis Bridge. It may be interesting to note that during the sinking of the two main piers of the Eads Bridge, twelve deaths from "Bends" occurred, and one death occurred sometime

afterwards. This in spite of the fact that all precautions then known to science had been taken. The "hospital lock" was not known at that time, and the men were made to work longer shifts. At 49 pounds pressure they worked three shifts of one hour each, while the modern schedule used at Metropolis Bridge would only permit two shifts of from forty minutes to one hour each.

Manufacture and Testing of Large Chains for the Fenders in the Panama Canal Locks

By Henry Goldmark, *M. W. S. E.*
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CHAIN cables consisting of welded links of wrought iron have been used for ships' anchors for over a hundred years, the material, the form of the link and the method of manufacturt remaining almost unchanged up to the present time. Chains of the same kind are also widely used in hoisting apparatus, steam shovels, dredges and similar heavy machinery. The size of anchor cables has increased greatly of recent years, as vessels required heavier and heavier anchors, and a like increase has taken place in the dimensions of hoisting chains. Anchor chains 3 inches in diameter are now not uncommon and 3¼-inch cables have lately been built for United States battleships and even larger ones for the British Navy. The S. S. Leviathan, formerly the Vaterland of the Hamburg-American Line, has still heavier cables with 4-inch links, 14½ inches wide and 24⅛ inches long, but their strength in the testing machine is understood to have been relatively low. Crane chains have rarely if ever reached such extreme dimensions; they usually have open links without studs.

With the exception of some of the smaller sizes, practically all chains have until recently been welded entirely by hand and in most chain works, machinery is not used in the preliminary operations of bending the links into shape and preparing the scarfed ends for welding. Under these conditions the strength of the chain—or of its proverbial weakest link—depends entirely on the skill of the individual smith and the care he gives to his work. It has therefore been impossible to predict the breaking strength of any given cable, within even moderately close limits, although with careful inspection and by using low working loads, chains have proved reliable and satisfactory in service.

METHODS OF TESTING CHAINS

The methods of testing chains were evolved mainly in Great Britain and have remained unchanged for a long time.

The tests generally specified are twofold:

(A) A test to destruction, made on one or more test pieces, two or three links in length, cut from each "shot" of cable.

(B) A proof test on each length of chain, the load being from 1/3 to ½ of the specified breaking strength.

As the "doublets" or "triplets" commonly break in the welds, the first test is mainly a check on the care taken by the mechanics in the welding. The variations in the breaking strength are quite considerable in different links, much greater than in eye-bars, for

instance, and there is no assurance that other links in the same length may not be much weaker than the small number broken in the testing machine.

The second or proof test is intended for detecting exceptionally weak links and for fixing a safe working load for the chains as a whole. In other kinds of structural work proof tests have generally been abandoned, as likely to cause injuries to the metal which cannot be detected by external inspection. In welded chains, however, they can hardly be dispensed with.

In crane chains, where a failure may imperil human life, the risk is reduced by using very low working stresses in service, sometimes as low as a sixth of the proof stress, by annealing the chains from time to time and, in some cases, as an extra precaution, by discarding the chains after they have been used for a certain length of time.

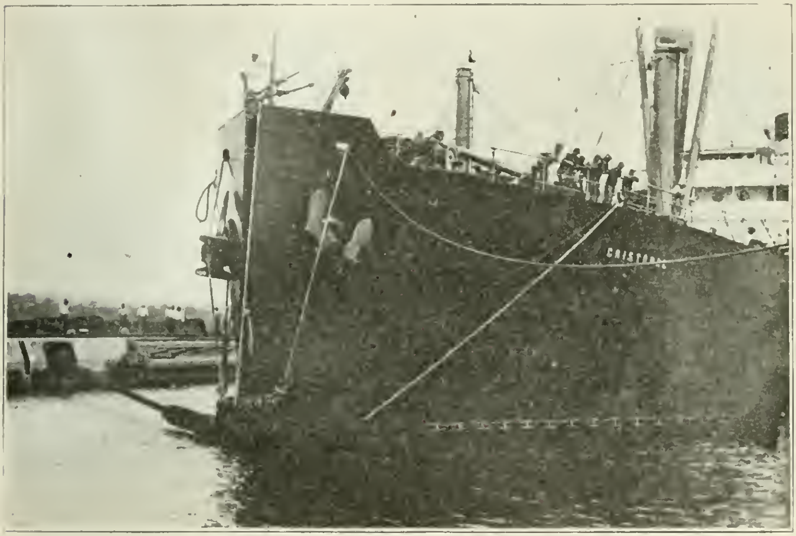

Fig. 1

DESCRIPTION OF CHAINS USED AT PANAMA

The author designed and supervised the construction of machinery of an unusual character requiring a large number of very heavy chains in which ample strength and reliability were of the utmost importance. Many difficulties were met with in their manufacture and a new and improved method of making the chains by power forging was adopted before the order was entirely completed. It was thought that an account of the results obtained in the tests, which were unusually elaborate, might be worthy of record and of interest to members of this society.

The chains in question are installed in the locks of the Panama Canal, as fenders for protecting the lock gates from injury by

vessels using the locks. These fenders are described in detail in a paper presented to the International Engineering Congress at San Francisco in September, 1915.*

The chains are normally stretched across the lock-chambers near the top of the walls, and lowered to the bottom to permit the passage of vessels. The raising and lowering is effected by large hydraulic cylinders placed vertically in the lock-walls and connected to the chains by a system of grooved sheaves. When a chain is struck by a vessel it pays out under strain, gradually bringing the latter to rest, the pull on the chain being controlled by relief valves attached to the operating cylinders and set to a proper pressure.

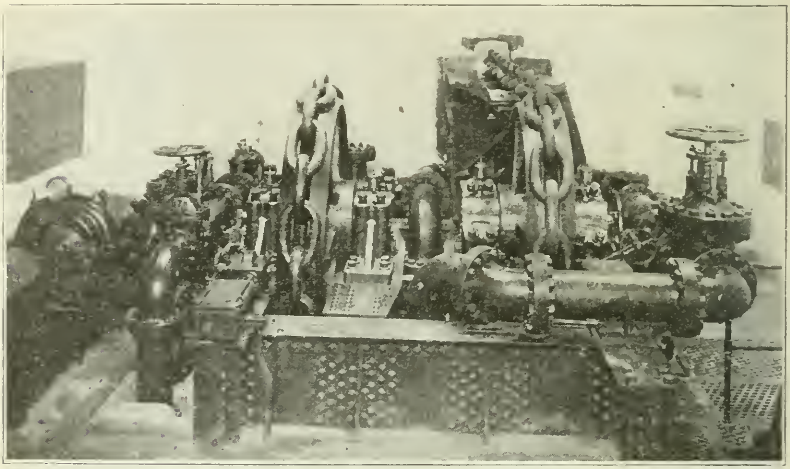

Fig. 2

One of the chains in its raised position is shown in Fig. 1, which was made from a photograph taken during the final tests. In these the steamer Christobal, having a displacement of 18,000 tons and moving at a speed of 2½ miles per hour, was brought to rest within a distance of about 50 feet without injury to the vessel or the chain. The wrappings on the cable were temporary.

The diameter of the chain links was fixed at 3 inches and the pull during operation at 220,000 pounds, as it was believed that this would give sufficient stopping power without requiring the fender machines to be of excessive dimensions. It was thought that there would be no special difficulty in securing 3-inch chains of proper strength. It proved, however, that few plants in the United States had either the experience or the equipment necessary for making chains as large as 3 inches, and the progress of

* Lockgates, Chain Fenders and Lock Entrance Caissons of the Panama Canal, by Henry Goldmark, late designing engineer of the Isthmian Canal Commission.

manufacture was very slow. As 24 chains were required with a total length of 10,500 feet and a total weight of 500 tons, it took over a year and a half to complete the order and there was much difficulty in securing the desired strength and uniformity. Eight of the chains were made at the United States Navy Yard at Boston, thirteen at private works in the United States, and three in England.

Three sections are used in each fender, a central section, with stud links, about 100 feet in length, spanning the lock-chamber, and two end sections of about 150 feet each, which pass around the sheaves and are of the open link type without studs.

A general view of the machinery, showing the open link chain, passing over the sheaves, is given in Fig. 2. The general arrangement of the chains and details of the standard links are shown in Figs. 3, 4 and 5. At the end of each section of the chain a few special links of slightly different shape are used to facilitate the attachment of the shackles. The studded and open links in the chains as finally built are of exactly the same shape and size, being 17 inches long and 10¾ inches wide, in accordance with U. S. Navy standards for anchor chains.

REQUIREMENTS AS TO STRENGTH OF CHAINS

No definite agreement has been reached as to the breaking and proof loads which should be required in such large chains. The British Admiralty has fixed the statutory breaking stress for stud chains up to 2½ inches in diameter at 38,400 pounds per square inch of metal or 80 per cent of the strength of the bar, if taken at 48,000 pounds per square inch. For larger sizes, the stress specified decreases gradually, so that for a 3-inch stud chain the breaking load is 490,000 pounds or only 72 per cent of the bar strength. The proof loads are fixed at two-thirds of the breaking strength for all sizes, which gives 326,600 pounds for 3-inch chains. The U. S. Navy requirements are slightly less than the British for chains of moderate size, but no reduction is made in the case of larger sizes. For 3-inch stud chains, the statutory breaking stress is 525,100 pounds or 77 per cent of the bar strength. The proof load is 58 per cent of the breaking load for 2-inch chains, increasing slightly for larger sizes. For 3-inch chains it is fixed at 312,000 pounds.

The relative strength of open link and studded chains has long been a mooted question. On the basis of extended experiments, a board of U. S. Navy Engineers* in 1897 reported the stud link to be the weaker, and some European authorities agree with this view. On the other hand, practically chain makers have generally believed the stud link to be stronger by 10 per cent or more. As a matter of fact, open link chains as large as 3 inches in diameter have rarely, if ever, been manufactured on an extended scale, so

* Experiments of Committee D of the U. S. Board, Commander L. A. Beardslee, Chairman. (Executive Document No. 98, House of Representatives 45th Congress, Second Session.)

that no data were at hand for predicting what the strength of the open link chains required at Panama would be.

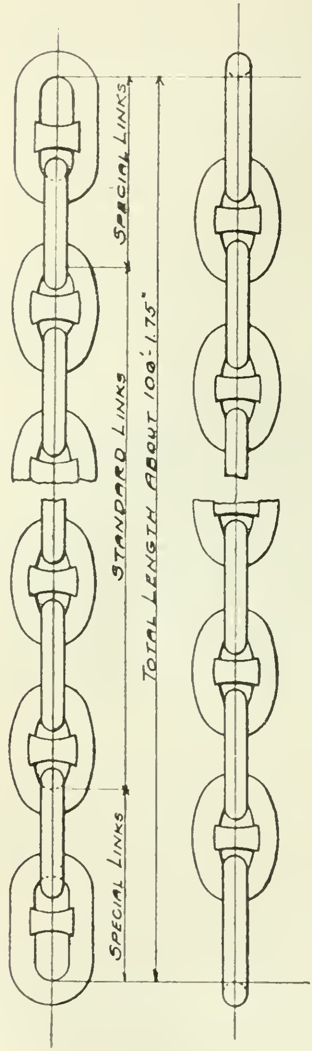

Fig. 3

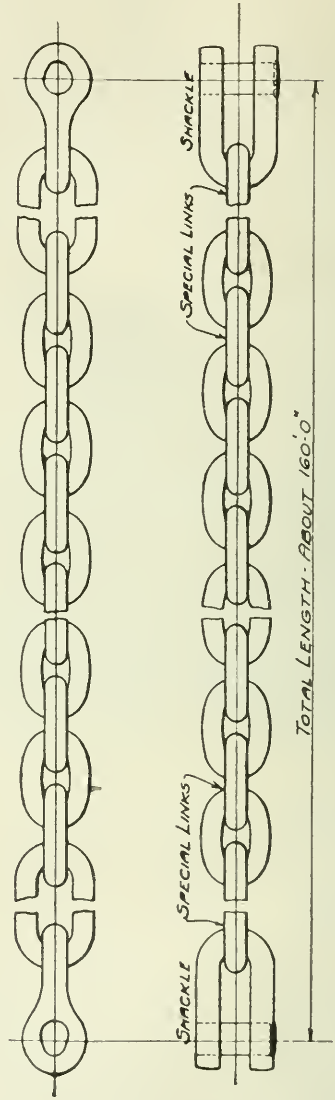

Fig. 4

It is believed that the full record of the tests made on the two types, which is given below, will prove of interest in this connection, especially as all the links were of exactly the same shape and size. It will be seen that the average strength of the stud links was somewhat the greater.

FIRST OR SAMPLE CHAIN

A complete chain, consisting of one stud and two open link sections was first ordered for trial. The stud links were of the standard size, the open links in this first chain somewhat smaller than the stud links, being only 10 inches wide and 14 inches long. Each complete section was given a proof test at the Boston Navy Yard of 242,000 pounds, while several triplets cut from the chains were tested to destruction. They showed a breaking strength of over 500,000 pounds for the stud and 457,000 pounds for the open links. On the Isthmus one of these open link sections attached to a fender machine was put under strain by exerting a pull from a large winding engine. After numerous tests under smaller loads, it broke in a defective weld under a pull of about 220,000 pounds, which included an ample allowance for the frictional resistances

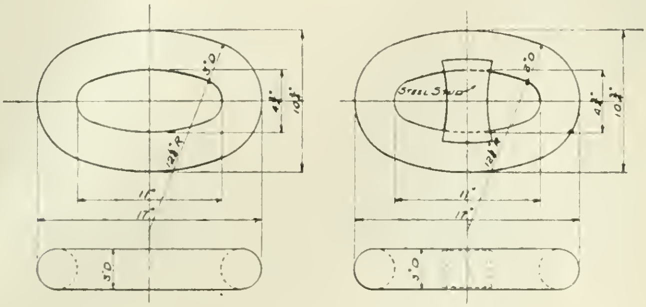

Fig. 5.

of the machinery, etc. In view of the unexpected weakness shown, the broken chain was returned to the U. S. for further invesigation.

Two sections about 35 feet long were tested to destruction, one of which was annealed before testing. The unannealed chain broke at 350,000 pounds, the permanent set being 3½ per cent of the chain length; the corresponding figures for the annealed section were 360,000 pounds and 5 per cent, so that the annealing, although carefully done in an oil furnace at 1550 degrees F., seemed to have little or no effect. The break was in both cases in a defective weld, and a number of other links showed incipient failure at the welds. The fractures were almost wholly granular.

SECOND SET OF TEST CHAINS

In view of these results it was decided to make some further tests before giving the final order, so in order to determine the most suitable material and method of manufacture, the best form for the links and the proper breaking and proof strengths to be required. Four test chains about 50 feet long were therefore ordered —two, one with stud and one with open links from the Boston Navy Yard, and two from Messrs. Bradlee & Company of Philadelphia,

among the most experienced private manufacturers in the United States.

The wrought iron bars for all four chains were purchased and tested by the canal authorities. The highest grade of double refined iron, entirely free from scrap, was specified. All muck bars used for rolling the finished 3 1/16 rounds were second rolled and smooth with clean sharp edges and of the full length required, and no short or crop end bars were permitted. The rolling was very carefully done so as to obtain the highest attainable perfection in the product. The piles, which were 7 inches square and 31 inches long, were placed in the heating furnace in rows of eight, where they

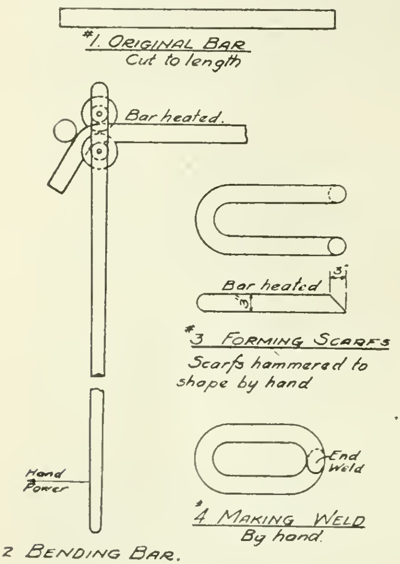

Fig. 6.

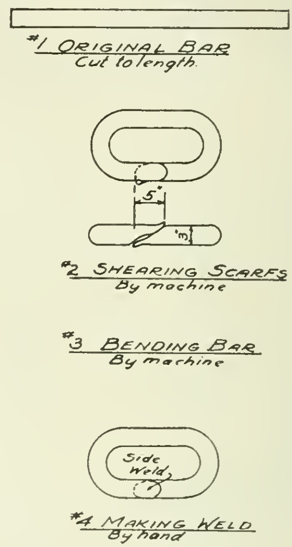

Fig. 7.

remained about one hour, or long enough to come to a welding heat. They were next passed twice through the roughing rolls, turning the piles at the second pass and then returned to the furnace and soaked so as to bring them to a uniform temperature for final rolling. During this final rolling, the bars were turned at each pass. They were passed through the last set of grooves four times to ensure perfect roundness.

The chemical and tensile tests gave the following results:

	Test Piece No. 1	Test Piece No. 2	Test Piece No. 3
Carbon, percent	.04	.05	.05
Sulphur, percent	.003	.002	.002
Manganese, percent	.05	.04	.04
Phosphorus, percent	.098	.096	.097
Silicon, percent	.13	.18	.12
Elastic Limit lbs. per sq. in.	33,500	33,340	33,680
Ultimate Strength lbs. per sq. in.	47,820	47,850	47,000
Elongation percent in 8 inches	39.0	38.5	42.5
Reduction of Area, percent	42.0	43.3	45.2

The bending tests indicated extreme ductility, and the fractures, in the tensile tests, were of half cup shape and showed a long silky texture.

The methods of manufacture used in making the chains at the two works were somewhat different, as indicated in the sketches given below, which show the successive steps in the process. (See Figs. 6 and 7.) It will be noted that in the Navy chain the weld is at the ends of the links, while the Philadelphia chain is side welded. As far as known to the author, end welding in the United States is used only by the Navy Department, and in Europe also nearly all chains are side welded. There appears to be little difference in the strength of the two types.

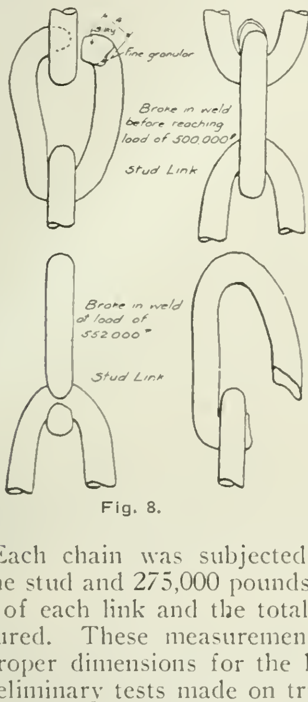

Fig. 8.

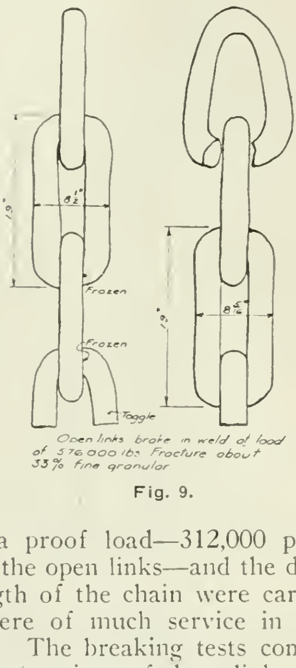

Fig. 9.

Each chain was subjected to a proof load—312,000 pounds for the stud and 275,000 pounds for the open links—and the dimensions of each link and the total length of the chain were carefully measured. These measurements were of much service in fixing the proper dimensions for the links. The breaking tests consisted of preliminary tests made on triplets (sections of three links each) and final tests on the complete sections. The results are given in the following table:

TABLE A.

BREAKING STRENGTH OF 4 TEST CHAINS

(About 35 feet long)

(A) STUD LINK CHAIN.

Test No. 1.	U. S. Navy Chain, Triplet No. 1	552,000 pounds
Test No. 2.	U. S. Navy Chain, Triplet No. 2	500,000 pounds
Test No. 3.	U. S. Navy Chain, full length, 1st test	440,000 pounds
Test No. 4.	U. S. Navy Chain, full length, 2nd test	480,000 pounds
Test No. 5.	Bradlee Chain, Triplet No. 1	564,000 pounds
Test No. 6.	Bradlee Chain, Triplet No. 2	578,000 pounds
Test No. 7.	Bradlee Chain, full length, 1st test	470,000 pounds
Test No. 8.	Bradlee Chain, full length, 2nd test	530,000 pounds
	Average	514,250 pounds

(B) OPEN LINK CHAIN.

Test No. 9.	U. S. Navy Chain, Triplet No. 1	576,000 pounds
Test No. 10.	U. S. Navy Chain, Triplet No. 2	556,000 pounds
Test No. 11.	U. S. Navy Chain, Triplet No. 3	500,000 pounds
Test No. 12.	U. S. Navy Chain, full length, 1st test	580,000 pounds
Test No. 13.	U. S. Navy Chain, full length, 2nd test	375,000 pounds
Test No. 14.	Bradlee Chain, Triplet No. 1	528,000 pounds
Test No. 15.	Bradlee Chain, Triplet No. 2	450,000 pounds
Test No. 16.	Bradlee Chain, Triplet No. 3	428,000 pounds
Test No. 17.	Bradlee Chain, Triplet No. 4	526,000 pounds
Test No. 18.	Bradlee Chain, Triplet No. 5	428,000 pounds
Test No. 19.	Bradlee Chain, full length, 1st test	400,000 pounds
Test No. 20.	Bradlee Chain, full length, 2nd test	410,000 pounds
Average		463,080 pounds

The second test in the case of full length tests was made after coupling the broken sections together by a shackle. Each load from 50,000 pounds to the one next below was held for one-half minute and then dropped to 10,000 pounds for measuring the length of the chain. All the breaks occurred at the weld excepting in Test No. 7, which broke across the bar. The figures in the table show the wide variations in strength characteristic of all chain tests, the maximum breaking load being as much as 30 to 50 per cent greater than the minimum for the same type.

The full length tests, made on 25 links or so, naturally gave, as a rule, somewhat lower values than the tests on triplets. A comparison of the open link and stud chains shows the former to have 15 per cent less strength, if the weakest chains of each kind are compared, and the same ratio holds for the average strength of all link tests. On the other hand, there is but little difference between the maximum values obtained for the two types. There is also no marked difference between the chains made at the two plants. Figs. 8 and 9 show some typical deformations and fractures obtained in these tests.

The specifications for the final chain order, which are summarized below, were drawn up on the basis of the results obtained with the test chains, and proved on the whole very satisfactory, although as the work progressed it was necessary to reduce their requirements to some extent.

SUMMARY OF SPECIFICATIONS FOR CHAINS

Material: All iron shall be of the best make and without steel scrap, smoothly rolled, truly round, free from slivers, depressions, seams, crop ends, cracks, flaws, scabs, cavities, cinder patches, and evidences of being burnt, or other defects. It must be of a long and silky fibre. The use of hard or crystalline iron will not be permitted.

The bundles prepared for rolling must consist of double refined iron, closely and carefully laid and tied. The bars must be straight and in one length; the use of short pieces will not be tolerated. The finished bars shall be round and smooth and their diameter shall not vary more than 1/32 inch from the required diameter.

The iron in finished bars must have a tensile strength of not less than 46,000 pounds per square inch nor more than 47,500

pounds per spare inch; an elastic limit of about 60 per cent of the breaking strain, an elongation of at least 30 per cent in a length of 8 inches, and a contraction of area of at least 40 per cent. One or more tensile test pieces shall be taken from each lot of 50 or less of the finished bars, the tests to be made on full size bars.

Bolts cut from 1 per cent of the bars must stand bending cold both ways until the sides are brought parallel and separated from each other not more than one-half inch without showing signs of fracture or flaw. They must also stand bending at a dull-red heat until the sides are close together without any sign of fracture or flaw. Bolts shall also be nicked and broken cold by slow bending, and must show a fibrous section.

The studs shall be made of good cast or wrought steel, free from blow holes or other defects.

The shapes of the links after proof test shall be as shown on the contract drawings. Their length shall not vary more than ⅝ inch nor their width ¼ inch from the theoretical dimensions, and the diameter of the iron in the finished links shall not differ more than ⅛ inch from the figure shown on the drawing.

The length of the entire section of chain, after the proof test, must be within the limits shown on the plans.

Test of Triplets: The triplets shall be cut from the completed section, one triplet to be selected at random for every 60 feet of chain.

The tests will be considered satisfactory if—

(a) All triplets stand a pull of 500,000 pounds before breaking in case of the stud links, or

(b) All triplets stand a pull of 450,000 pounds before breaking in case of the open links.

Two additional triplets will be selected for further tests for each triplet that fails to stand the test under (a) or (b).

The section will be rejected in case, in these retests

(c) Any stud link triplet breaks before reaching a load of 450,000 pounds, or

(d) Any open link triplet breaks before reaching a load of 400,000 pounds.

All triplets shall be pulled to destruction, but it will not be necessary to apply a load over 550,000 pounds.

Proof Tests: Each entire section of the chain, including shackles, shall be proof-tested after satisfactory tests on the triplets have been obtained.

The following proof loads shall be applied:

(a) For stud link chain, 300,000 pounds.

(b) For open link chain, 275,000 pounds.

The chain will be rejected if it fails to sustain the proof load which shall be sustained for not less than one minute before the load is removed.

The chain must be smooth, the links regular in shape, the studs properly spaced, free from cold welds or burnt welds, cracks or overlaps, and have a workmanlike finish. Links must not be less than the nominal size in the body of the weld. Any chain in these respects shall be rejected until the defective links have been replaced. If deemed necessary by the representative of the Commission, the corrected pieces will again be subjected to the proof-strain until they are found to be satisfactory.

Shackles: The shackles should be of wrought steel die-forged. One shackle from every lot of twenty or less will be selected for test. If any of these test pieces fail, the total number of test samples will be doubled and a second failure will require the rejection of the entire lot. The breaking and proof-strains of connecting links and shackles must be the same as specified for the stud link chains.

Testing Machine: The capacity of the machine used for testing the triplets and shackles shall be not less than 600,000 pounds, and the machine shall be graduated for this load. Its accuracy shall be verified at the contractor's expense in case the representative of the Commission considers it necessary.

The complete record of the tests obtained on the nine chains (9 stud and 18 open link sections) manufactured at the Boston Navy Yard is given in Table C. The tests made on the wrought iron bars used for making the chains are also given in Table B. High grade iron of this kind is but little used of late years, and the degree of uniformity which can be obtained is worth noting. It may be well to add that the lower tensile strength shown by the wrought iron in the later tests was intentional, as it was found that better welds were obtained with 46,000 pound iron than with that of higher strength.

TABLE B.

TEST OF WROUGHT IRON BARS FOR CHAINS

Serial No. of Test Piece	Chemical Analysis C.	P.	S.	Si.	Mn.	Physical Test Elastic Limit No. per sq. in.	Ultimate Stgh. No. per. sq. in.	Elong. in 8" %	Reduction of area. %
No. 1	.05	.046	.009	.120	.07	27990	49090	37.5	43.2
No. 2	.06	.087	.011	.160	.10	29150	49850	38.5	41.1
No. 3	.06	.069	.009	.160	.07	29550	49490	39.0	42.6
No. 4	.04	.062	.010	.130	.08	30215	49700	38.5	40.1
No. 5	.07	.054	.008	.135	.07	26440	48250	37.5	44.7
No. 6	.06	.046	.009	.146	.08	26645	48250	37.5	42.3
No. 7	.06	.055	.012	.150	.08	26850	48590	38.5	40.3
No. 8	.07	.054	.008	.135	.07	26440	48250	37.5	44.7
No. 9	.06	.046	.009	.146	.08	26645	48660	37.5	42.3
No. 10	.06	.055	.012	.150	.08	26850	48590	38.5	40.3
No. 11	.05	.034	.008	.130	.06	23850	46245	40.0	43.0
No. 12	...	....	....	....	...	26500	46220	37.5	45.0
No. 13	.06	.043	.010	.174	.07	25640	46040	39.0	35.0
No. 14	.06	.046	.012	.188	.08	25980	46270	35.0	40.6
No. 15	.06	.042	.012	.156	.09	24540	46600	32.0	41.2
No. 16	.06	.049	.010	.244	.07	25130	45175	36.2	41.5
No. 17	.06	.042	.008	.180	.05	25175	47030	37.5	39.6
No. 18	.05	.041	.008	.166	.06	25230	47180	36.2	41.3
No. 19	.06	.038	.010	.170	.08	25970	46040	32.5	41.1
No. 20	...	....	....	....	...	26500	47590	28.0	40.6

TABLE C.

TESTS OF TRIPLETS FROM NINE COMPLETE CHAINS

CHAIN FENDERS OF PANAMA CANAL.

9 STUD LINK SECTIONS ABOUT 106 FT. LONG—115 LINKS.

(a) Hand Forged Chain

Chain Section	ORIGINAL TEST			FIRST RETEST				SECOND RETEST		
	1st Triplet	2nd Triplet	3rd Triplet	1st Triplet	2nd Triplet	3rd Triplet	4th Triplet	1st Triplet	2nd Triplet	3rd Triplet
212	466,000	487,000		444,000	392,000	472,000	490,000	374,000	441,000	
213	508,000	484,000		460,000	496,000					
214	540,000	536,000								
215	472,000	526,000		490,000	512,000					
216	510,000*	530,000*								
217	528,000*	525,000*								
226	525,000*	525,000*								
(b) Power Forged Chain										
235	474,000	464,000	522,000	474,000	440,000					
240	434,000	490,000	512,000	462,000	450,000					

18 OPEN LINK SECTIONS GENERALLY ABOUT 150 FT. LONG.
(About 170 Links)

(a) Hand Forged Chains

Chain Section	ORIGINAL TEST 1st Triplet	2nd Triplet	3rd Triplet	FIRST RETEST 1st Triplet	2nd Triplet	3rd Triplet	4th Triplet	SECOND RETEST 1st Triplet	2nd Triplet	3rd Triplet
219	446,000	400,000	506,000	544,000	372,000	470,000	508,000	344,000	420,000	
218	464,000	510,000	438,000	360,000	440,000			390,000	526,000	
220	452,000	438,000	440,000	440,000	452,000	520,000	312,000	384,000	470,000	
221	340,000	424,000		474,000	362,000	392,000		404,000	468,000	574,000*
222	479,000	396,000	504,000	474,000	464,000	510,000*	510,000*			
223	510,000*	500,000	375,000	426,000	398,000					
224	482,000	464,000	432,000	496,000	436,000					
227	510,000*	480,000	510,000*							
228	469,000	388,000	462,000	482,000	480,000	468,000				
229	532,000	418,000	452,000	392,000	430,000	428,000				
230	491,000	514,000	512,000							
231	460,000	368,000	188,000	494,000	344,000	493,000	366,000	440,000	482,000	510,000*
232	486,000	510,000*								
233	468,000									
234	510,000*									

(b) Power Forged Chains — Original Tests

Chain Section	1st Triplet	2nd Triplet	3rd Triplet	4th Triplet	5th Triplet	6th Triplet	7th Triplet	8th Triplet		
236**	498,000	522,000	536,000	492,000	444,000	496,000	542,000	480,000		
237**	524,000	524,000	510,000	504,000	580,000	560,000				
238	562,000	525,000	530,000							
239	560,000	520,000	532,000							

* Indicates that the load in question was reached without breaking the chain.
** These are special sections 280 and 290 feet long.

It will be noted that the chains were partly hand and partly power forged. The different steps in the process of hand forging are described in a valuable paper by Naval Constructor J. E. Otterson, published a few years ago.*

The results for the hand made links did not differ greatly from those previously obtained in the case of the test chains, either as to the uniformity or the absolute strength of the triplets. The average breaking load for all links broken was 488,750 pounds for the stud chain and for the open chain 450,700 pounds, or eight per cent less. Practically all the chains broke at the welds.

POWER FORGED CHAINS

These were made by a process which has been developed at the Boston Navy Yard during the last few years. At the time when the Panama chains were begun, the method was not sufficiently perfected to warrant its adoption for such difficult work. It was used, however, with excellent results on the last six sections, and since then is understood to have entirely supplanted hand forging in making heavy chains for American warships.

The process and its gradual evolution are fully described in several interesting papers by Naval Constructor F. G. Coburn, U. S. N., recently published.**

The successive steps required to make a complete chain may be briefly summarized as follows:

The bar iron is first cut in heavy shears into bolts, each of proper length to make one link. Each bolt is then heated at one end and placed in an upsetting machine, which upsets and bends it to an angle of about 90 degrees. In the same heat, the scarf is put on under a 2,500 pound steam hammer. The bolt is then again heated and the other end bent and scarfed in the same way.

The next step is the bending of the link, which is "end welded," to its proper shape. This is done in an 100 ton hydraulic forging press of the bull dozer type. The welding of the link, after it has been once more heated and threaded into the last link made, is done by two steam hammers operated by compressed air. The smaller, a 350-pound single frame hammer, is used to hammer the scarf thoroughly and does the greater part of the welding. The larger, a 3,000-pound double frame hammer, serves to give the link, which has again been heated, its correct shape and to bring the tips of the scarfs into close contact with the body of the link.

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* "Historical Notes on Chain Cables," by Assistant Naval Constructor John E. Otterson, U. S. N. Read before the Society of Naval Architects and Marine Engineers, on December 11, 1913.

** "Making Chains Under Steam Hammers." "The Iron Trade Review, January 6, 1916."

"The Power-forging of Chain Cables." A paper read before the Society of Naval Architects and Engineers, November 16, 1916.

"Heat Treatment of Wrought Iron Chain Cables," by F. G. Coburn, W. W. Webster and E. L. Patch. A paper presented before the American Society of Mechanical Engineers, December 8, 1916.

The last step is the heat treatment which has been found absolutely essential in power forged chains. It consists in heating the completed chains to about 1,600 degrees F. in an oil furnace and afterwards cooling it in air. A very careful regulation of the temperature is necessary. It will be seen that machinery is used throughout.

The power forged links are believed to be in every way superior to those made by hand. Although among the earliest made by this process, the power forged Panama chains gave far more uniform results in the testing machine than those made by hand, with fewer abnormally weak lines. There was little difference between the maximum and the average breaking loads. The dimensions and shapes of the links were more uniform and the surfaces more smoothly finished than in hand work, while the capacity of the plant was largely increased.

Hammer forging undoubtedly constitutes a great advance, even in the case of chains which can be made by hand without much difficulty. The limit of size suitable for hand forging seems, however, to have been reached in the case of the three-inch chains. For still larger sizes, power forging appears to be the only feasible method and its general adoption in such work seems assured. It may be interesting to mention that a method of power forging similar to that developed at the Boston Navy Yard has been in use for some years at the well known Chain Works of Messrs. Brown, Lenox & Co., Ltd., at Pontypridd, Wales.*

The designing and construction of the fender chains were under the immediate charge of the author as designing engineer for lock-gates and protective devices for the Isthmian Canal Commission, Brig.-Gen. H. F. Hodges, assistant chief engineer, being in general charge of the locks and dams and Maj.-Gen. G. W. Goethals, chairman and chief engineer of the Commission.

The inspection in the United States was under the general direction of Mr. J. M. Hammer, assistant engineer, with Mr. Frank Price as chief inspector, to whose intelligent and conscientious work the thorough inspection was largely due.

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* Engineering (London), January 12, 1917, p. 39.

Chicago, Burlington and Quincy Railway Bridge at Kansas City, Missouri

By G A. Haggander, M. W. S. E.,
Bridge Engineer, Chicago, Burlington & Quincy Railway Co.

Presented February 10, 1919.

THE original bridge at this location was the first one constructed across the Missouri River. The movement which led to its building dates from the incorporation of the Kansas City, Galseston and Lake Superior Railroad by the state of Missouri in 1857. At that time the population of Kansas City was about 2,000.

The Civil War put an end to building operations and actual work did not begin on the bridge until 1867, when Octave Chanute took charge of the work as chief engineer. The bridge was publicly opened on July 3, 1869. It consisted of the following spans: From north to south, A-177 feet, B-200 feet, C-250 feet, D-200 feet, E-363 feet draw, F-132 feet, G-68 feet, making the total length from outside to outside of masonry 1,400 feet. Spans A, B, C, D and F were of the double triangular truss type, in which the top chord, posts and braces were of wood, and the other members wrought iron; cast iron being used in the details and connections. The floor system consisted of wooden floor beams and stringers. Span "G" was a riveted lattice girder of wrought iron with wooden floor beams and stringers. The draw span was of the Pratt truss type, and was built of wrought iron, excepting that the stringers were of wood. The highway floor on the fixed spans consisted of two diagonal layers of 1¼-inch timber paved with 4-inch paving blocks, and a sidewalk on the west side of the bridge supported outside of the truss by brackets. The highway floor on the draw span was 2-inch oak planking and no sidewalk was provided. Piers Nos. 1, 2 and 3 were founded on piles and Nos. 4, 5 and 6 on what was thought to be bed rock, by sinking caissons by the open dredging method and filling them with concrete. Piers Nos. 7 and 8 and the south abutment were founded on solid rock. The stones used in the piers were limstone quarried in the bluffs within three miles of the bridge site. The face stones were cut, but the backing consisted of heavy uncut stone laid in mortar beds. Hydraulic cement of Louisville manufacture was used.

In 1876 span A was destroyed by fire and replaced with a wrought iron span. It was again replaced in 1900. Span B was replaced in 1886, spans C and D in 1889, span G in 1891, and spans E and F in 1892.

A cavity was discovered under pier No. 6, the pivot pier, about the year 1872, and in 1882 a pneumatic caisson of timber construction was sunk around it. Not much is known of this work and it was evidently abandoned before reaching the bottom of the pier,

the space between it and the masonry being filled with concrete. In 1888 a further examination of the foundation was made by means of a shaft driven into the pier and down toward the base, but the work was abandoned on account of water. It was continued in 1889 under air pressure. When the shaft reached the base of the pier, drifts were driven in four different directions and it was found that the pier had been founded on boulders underlaid with sand and gravel, making it liable to damage from scour. In 1891 a steel caisson was sunk around the pier, through the timber one sunk in 1882. When the cutting edge reached the bottom of the pier, sand began to flow in, causing it to settle. The working chamber was at once filled with concrete, as was the space between the caisson and pier.

Piers Nos. 1 to 7 inclusive were heavily banded with rails in 1889, as the masonry was disintegrating very badly. The tops of piers Nos. 3 and 4 were strengthened and tied together by placing rail seats under the pedestals and the tops of piers Nos. 5, 6 and 7 were replaced with concrete about the same time. The top of pier No. 2 was reinforced with concrete in 1914. Pier No. 8 was renewed in 1890.

It was generally known that on account of insufficient width of clear openings and unfavorable angle with the direction of the general flow of the water, the bridge was objectionable to navigation interests, and plans had been prepared for the time when the change would be required. Borings were made in 1910 by the railroad company's forces and the location and desirable span lengths decided upon.

On May 22, 1915, the railroad company was notified that the bridge must be altered. The resident engineer arrived at Kansas City on June 3, 1915, but the high water seriously delayed the starting of the work and it was not until August 10 that a material track was completed to the river bank. On August 16, 1915, the cutting edge was placed for pier No. 1. The air was put on September 7 and caissons sealed on October 6, 1915. The work on the main piers was completed on February 18, 1916.

The building of the main piers was contracted to the Union Bridge & Construction Company, Kansas City, Mo. The contract for the superstructure was awarded to the American Bridge Company in the fall of 1915. It was the intention to erect the superstructure during the following winter, but on account of the unsettled condition of the steel market the erection was delayed until 1916. The American Bridge Company's force erected the highway approaches, approach girders and the two 330-foot spans during the summer and fall of 1916, and the draw-span during the winter when navigation was closed.

The bridge was opened for traffic on February 1, 1917, and the wrecking of the old structure was immediately started, as the new draw-span could not be swung until the old one was removed.

The wrecking of the sub-structure and superstructure was done by the same contractors who built the new bridge.

The new bridge was constructed on the same grade as the old one, the alignment at the south end corresponding to that of the old bridge but being about 200 feet upstream at the north end. This made the axis of the new bridge at right angles to the harbor lines. The fact that the north end of the bridge was 200 feet upstream from the old bridge necessitated the building of an embankment 1,400 feet long on a .52 per cent grade, having in it a reinforced concrete subway 18 feet wide and 13 feet high for highway traffic. The fill contained about 100,000 cubic yards of material and was placed by a dredge in the river, pumping sand through a 15-inch pipe, except for a small amount placed on top by train. The highway approach on this side contained 32,000 cubic yards of fill, which was placed in a similar manner.

The bridge is constructed for double-track railroad traffic, the tracks being 13-foot centers, and has an upper deck with a 20-foot roadway for highway traffic. This upper deck is directly above the railroad deck between piers Nos. 1 and 6, and from these points is carried by an independent steel structure supported on concrete piers on a different alignment and descending on a 7 per cent grade. The highway beyond the steel structure at the north end consists of an embankment, while at the south end 150 lineal feet of timber trestle and an embankment were put in, the trestle being over some proposed tracks. The highway deck is paved with creosoted blocks.

The draw protection consists of creosoted pile bents, sheathed and protected at the upstream and by a concrete pier sunk by the pneumatic process. The sheerboom above pier No. 5 consists of creosoted pile bents, sheathed and protected at the upstream end by a creosoted timber crib sunk by the open dredging method.

Pier No. 1 was located immediately north of the north harbor line while pier No. 6 was located south of the harbor line. A 75-foot deck plate girder span was located north of pier No. 1 to prevent the slope of the approach embankment from extending beyond the harbor line. The skewed through plate girder spans were placed south of pier No. 6, one being located over Front Street and the Missouri Pacific tracks, the other over the location of future tracks. A 120-foot deck plate girder span located between piers Nos. 5 and 6 brought the south arm of the draw span over the main channel of the river, the draw span being 450 feet long to provide two 200-foot clear openings. Two spans, each 330 feet long, complete the bridge. Briefly, the bridge consists of the following spans from north to south: One 75-foot deck plate girder span, two 330-foot truss spans, one 450-foot draw span, one 120-foot deck plate girder span, one 96-foot through skew plate girder span, and one 65-foot through skew plate girder span, the distance face to face of parapets along the center line of track being 1,486 feet 4¾ inches.

The main sub-structure consists of five concrete piers, Nos. 1

to 5, inclusive, which were founded on pneumatic caissons. The caissons for piers Nos. 2, 3 and 5 are all of the same horizontal dimensions, 24 feet wide, 66 feet long and 15 feet 6 inches high. The caisson for pier No. 1 is 21 feet wide, 64 feet long and 15 feet 6 inches high. The caisson for pier No. 4, which is the pivot pier of the draw span, is hexagonal in shape, the distance between the parallel sides being 45 feet. It is 34 feet 6 inches high. The caissons which were built in place are of timber construction surmounted by a timber crib of varying height, filled with concrete.

The caissons for piers Nos. 1 and 2 were laid directly on the ground, but the caissons for piers Nos. 3, 4 and 5 were built in a pile dock at the pier sites and lowered with lowering screws.

The cutting edges of the caisson consist of 15-inch by 18-inch timber protected by a built-up steel section. The rest of timber used is mainly 12 inches by 12 inches, the outer course being horizontal and the inner course vertical and sheeted on the outside with 3-inch by 10-inch timbers placed vertically.

The caissons were sunk to rock and enough penetration secured to prevent undermining on account of erosion of the river bed. They were sealed with concrete. Each caisson was equipped with one man shaft, two material shafts, three to four 4-inch blow pipes and the necessary air and water pipes, as well as telephones coning to the power house and derrick house.

A grid of transverse and longitudinal 1¼-inch square reinforcing bars was placed in the concrete above the roof of the working chamber. The shafts of the piers, above the crib, were reinforced with 1-inch square reinforcing bars placed 2 feet centers both longitudinally and vertically in a grid 9 inches from the face of the concrete, tied into the body of the pier by 1-inch bars about 5 feet 6 inches long, hooked around them and spaced about 4 feet horizontally and 8 feet vertically. The coping of the piers is reinforced by two grids of 1-inch bars spaced 1-foot centers, the top grid being 6 inches from the surface of the concrete and the bottom grid 2 feet below the top one.

All piers were connected by a temporary tramway extending from the north shore, and placed upstream from the bridge line. On this tramway were laid three tracks, two for operating concrete cars to and from the piers and one for a running track for the locomotive crane. The concrete plant was located on the north shore and consisted of a 20-foot by 20-foot gravel storage bin holding 300 cubic yards elevated on piling over a one cubic yard mixer, from which the concrete was dumped directly into cars on the tramway track. Gravel was elevated to the hopper by an endless bucket hoist.

Piers Nos. 1, 2, 3 and 4 were concreted from the plant on the north shore. On January 21, 1916, the ice took out 600 feet of the tramway. Pier No. 5 was concreted from a plant on the south bank. The air and water lines were carried on the tramway for piers Nos. 1, 2, 3 and 4, but were moved to the old bridge for pier No. 5. To reach pier No. 5 it was necessary to cross the main

river channel, necessitating the building of a lift span 80 feet long. This span was constructed in halves, each part being supported by cables connected with towers at each end and so arranged that each part could be lifted when necessary. Pier No. 6 was an open concrete caisson 17 feet wide and 57 feet long, divided into four excavating pockets by means of three transverse walls. The caisson was sunk by excavating the material from the four pockets by means of a clam shell bucket. The foundation of pier No. 7 and the south abutment were well above the water line and were easily constructed without the use of cofferdams.

All concrete aggregate used on this work was Sheridan pit run gravel obtained from the railroad company's pit at Sheridan, Ill. The proportions of concrete used were one part of cement to four parts of gravel in the neat work and working chambers of the piers, and a 1 to 6 mixture in the balance of the footings. The piers were bush hammered above the low water line after completion.

The main compression members of the 330-foot spans were H-section columns with a solid diaphragm in the center. In order to keep water and cinders from standing on this diaphragm a chord cover of 1/16-inch metal was used.

The highway deck consisted of creosoted paving blocks laid on creosoted sub-planking. Fire protection was provided by painting the bottom and sides of the sub-planking with fire resisting paint and by placing a layer of asbestos board under them. A membrane waterproofing, consisting of two ply of cotton cloth saturated and mopped with asphalt, was placed on the sub-planking and protected with asphalt and sand mastic.

The railroad deck consisted of creosoted timber ties, fender and guard rail. To protect the stringer flanges from brine drippings a sheet of zinc was laid over them and protected from the rubbing of the ties by a one-inch timber shim. The brine soon corroded the zinc, which was renewed. The flanges are now being protected by painting them two times per year with crude oil, which method has proven very satisfactory.

This bridge was designed for a live load consisting of two Coopers E-90 engines followed by a uniform live load of 7,500 pounds per foot of track on each track. This load was used for the hip verticals, hangers, sub-diagonals and floor system, while for the balance of the trusses the full load was used on one track and the uniform load only on the other. Fifty per cent of the live load stresses were added to take care of impact on the floor system and secondary truss members, while ten per cent was added for chord and end posts, and twenty per cent for web members. Wind and centrifugal forces were also considered. The highway floor was designed for a live load of 100 pounds per square foot with a 20-ton traction engine, while the trusses were designed to carry only 50 pounds per square foot of highway.

The material used was as follows: Highway portion of structure and all floor and wind bracing—medium carbon steel. All eye-bars—

heat treated carbon steel. Main truss members, drum transom beams and loading girders—silicon steel.

The main unit stresses used were: Tension in silicon steel, 2,500 pounds per square inch. Medium steel on railroad portion, 18,000 pounds. For highway portion, 20,000 pounds. Heat treated steel, 35,000 pounds. Compression reduced by Gordon's formula for silicon steel, 30,000 pounds per square inch, and medium steel, 18,000 pounds for railroad portion, and medium steel, 20,000 pounds for highway portion. Higher stresses were allowed for wind stresses.

The heat treated eye-bars were substituted for nickel steel bars and are a departure from establishd practice. The tests were highly satisfactory and the cost was less than that of nickel steel. The silicon steel used was of the same quality as was used for the Metropolis bridge, described by Mr. Modjeski in this issue.

The most interesting features of the draw span are the center castings and drum, the end lift and the rail locks. The center casting of the draw span was designed for one-half of the dead load, while the other half was carried by the live ring under the drum. This load was put in by calculating the deflections necessary to properly distribute the stresses. It was the original intention to erect the draw span with the entire dead load on the live ring and to transfer a definite amount to the center by measuring the load applied by jacks to the transom beams, inserting shims between the center casting and transom beams when the desired deflection was obtained. This method was given up on account of lack of time and difficulty of carrying it out. The center and live ring are heavy enough to carry a large amount of overload in case of lack of proper distribution of stresses.

The draw span is operated by a 75-horsepower electric motor, or a 50-horsepower auxiliary gasoline engine. No hand power is provided for. The end lifts are unique in design, as they consist of a powerful toggle arrangement. The rail locks are operated by compressed air furnished by an electric driven compressor. Wearing strips were furnished for the tongue rails instead of using solid tongue rails of expensive material. Credit is due Mr. B. B. Carter for the draw bridge machinery design and to Mr. C. H. Norwood for its installation. The bridge is interlocked and has protection signals and derails at each end.

The first steel erection began on the north highway approach on April 20, 1916. The 75-foot girders between the north abutment and pier No. 1 followed. Driving of falsework piling for the 330-foot span between piers Nos. 1 and 2 began on April 26, and erection of steel on June 13, 1916. Erection of the span was completed on August 21. The erection of the 330-foot span from pier No. 2 to pier No. 3 followed between July 10 and October 19, 1916.

Considerable falsework erection was required for the placing of the south girder spans due to the convergence of the old and new bridges at this point. The work, however, was completed between June 29 and September 20, 1916, with no delays to traffic. Erec-

tion of falsework for the north arm of the draw span was started on September 2, 1916. The steel erection followed and after river navigation closed for the winter the falsework was continued from the center pier to the draw protection crib of the old bridge. From this point, the south arm of the draw span was erected as a cantilever and erection completed on January 5, 1917. Before the new draw span could be operated it was necessary to remove the old draw span, one 200-foot truss span and the top of the pivot pier of the old bridge. This was accomplished before the spring opening of river navigation. Between January 9 and February 17, 1917, the last of the erection, a 120-foot deck plate girder span, was completed. The field paint consisted of two coats of red lead. The highway deck was placed by the railroad company's forces between December 8, 1916, and August 24, 1917. The wrecking of the old spans and piers followed and the work was completed on December 31, 1918.

In tearing down the south abutment a small copper box was found containing data put there in a dedication service on August 21, 1867. This box contained numerous United States coins of various denominations, names of officers and artisans employed in the bridge construction, officers and directors of the railroad, the city officers of Kansas City for 1867, also several newspapers of that date, together with other data concerning the building of the bridge.

The south abutment and pier No. 8 were wrecked at the time the new substructure was built. Piers Nos. 6 and 7 were the next to be wrecked. The foundation of pier No. 7 was 17 feet below low water. The stone was removed to the water line by a stiff leg derrick on shore. The portion under water was dynamited and dredged out with a clam shell bucket. The masonry and concrete inside the steel shell of pier No. 6 were removed, using the shell as a cofferdam. When near the bottom the water broke through and the balance of the concrete was broken up with a spud bar and removed with a clam shell. The steel shell was cut to pieces by dynamite and removed.

Piers Nos. 1 and 2 were removed by excavating inside of the old cofferdams and all of the sound piles pulled. Many were broken off in pulling. Pier No. 3 was excavated inside of a steel sheet pile cofferdam and the piles pulled. Pier No. 4 was wrecked to the water line and a steel sheet pile cofferdam driven around it. However, a sudden rise of the river destroyed this and the pier was removed by blasting and dredging without a cofferdam. The foundation was 45 feet below low water. Pier No. 5 was removed by blasting and dredging inside a steel sheet pile cofferdam to a depth of 35 feet below low water. The old draw protection was also removed by blasting and dredging.

The new bridge was designed by Mr. C. H. Cartidge, who was vice-president of this society at the time of his death, in June, 1916. The sub-structure was completed under his direction. The task of

directing the work to completion was made easier by the complete coöperation and the skill of the contractors and of the U. S. Government engineers, who assisted us in every way possible.

The resident engineers were, succssively, J. H. Merriam, H. W. Smith, D. R. Donlin and W. McCready.

DISCUSSION.

W. A. Lacher, A. W. S. E.: While it may not be an engineering question, I would like to know about the highway deck. In the old structure they had the single deck floored over so it could be used for highway traffic, and there was some higway traffic between trains. What was the arrangement with regard to that? Was the railroad compelled to provide a highway deck or did they receive some compensation for providing it? What was the arrangement in this particular? Was that part of the original franchise?

Mr. Haggander: It was in the original charter granted to the railroad when the first bridge was built. The consideration given by the railroad company was the furnishing of this highway deck. If they didn't agree to it when they put up the new bridge the charter would be void. They were compelled to put it in. The railroad company did not want to put the highway deck on, because it is not a paying proposition for them, but they were compelled to put it on this bridge to save the charter.

The Chairman: The end toggles were operated by air, were they not?

Mr. Haggander: No, they were operated by a shaft from the power house in the center. The rail locks were operated by air.

Mr. Chairman: That tongue rail arrangement at the end worked pretty good, did it not?

Mr. Haggander: We originally had wooden ties under this rail lock, oak tie with a steel channel on each side, but we found that due to the tremendous impact at that point the ties crushed and the tongue rails broke, so we have taken out the timber and substituted all steel ties.

The Chairman: The wheels ride the gap very nicely, do they not, without much of a jar?

Mr. Haggander: Yes, about a quarter of an inch rise in the tongue rail. There is no appreciable jar there.

The Chairman: Have you the original wearing surface on the tongue rails that you put on?

Mr. Haggander: We have, excepting in cases where the tongue rail broke. They have been in service now for two years. Some of the wearing strips have been in service that long.

C. H. Norwood, M. W. S. E.: In one of the slides we saw a little white spot that reminds one of a pigeon coop. That is the operator's house. Last Saturday I stood in an operating house on the New York Central Lines and it was as big as this (indicating

about half of the meeting room of Western Society). Of course it was a signal tower as well. Engineers tuck the operator's house in between girders or put it up on top of the bridge, or some other out of the way place, and one is expected to do all his work and stand on his head sometimes in doing it. I am looking for sympathy and larger operators' houses.

The discussion on the rail lock matter is rather interesting, and is a point we might do well to speak of further. This bridge is not considered a high speed bridge. The traffic goes onto the bridge at a curve and goes off at a curve. The objectionable bounce of riding the tongue rails is hardly noticeable, whereas on some of the straightaway track an eighth of an inch would be decidedly objectionable. I had quite an argument with a prominent bridge engineer last week on that very point. There seems to be a difference of opinion among engineers as to the advisability of using the tongue rail. I would rather not give my own opinion in the matter, because sometimes I think it is very satisfactory and at other times I think it is questionable, depending on the location. I notice the practice of late has been, however, of coming back to the old form of lifting rail, especially on draw bridges. With better devices for protection and for insuring the rail coming down on the seat, and when it is on the seat, to thoroughly lock it, is a very fine construction for high speed track. The three-track bridge of the Chicago & Northwestern in Chicago is a high-speed track, although it is not a draw bridge; it is a lift bridge; yet the mitered rails will permit of very high traffic speed.

On the S. P. & S. Ry. Company's bridges at Portland, Ore., they have the sliding rails, some of which have been in service for five years. They have given remarkable satisfaction, though. I have ridden over these bridges several times, and would watch to see if I could feel the little jolt you would expect to get. You would feel it but it was not objectionable. The trouble with some engineers in designing the tongue rails is that they allow too much to wear and too little clearance. As a matter of fact these rails are standing up a good deal better than was expected; I have considerable success in heat treated shafts, and I am very anxious to try out a heat treated fairly high carbon steel tongue rail. The best results today are obtained from the manganese alloy steel, but this is so expensive and so hard to work that a somewhat cheaper steel would be welcome.

O. F. Dalstrom, M. W. S. E.: In one of the views the center pier was shown under excavation, and while the outer shell appeared to be of very good masonry, the interior appeared to be either a very poor grade of masonry or else it was concealed by the way it was broken up. I would like to ask in just what condition you found that pier when you wrecked it?

Mr. Haggander: The outer course was of cut stone, while the inside was just a rubble masonry laid in mortar. We found the piers very badly broken to pieces near the top. The vibration of

the trains had done this. All of the copings had been reinforced. We found that the stones were pretty badly broken up near the top, but the farther down we got the better the masonry was. When we got down below the water line we found it in excellent shape. It was banded very early in its life—in 1890. At that time the piers were just a little over twenty years old, and it was the bands that kept them together.

Question: What kind of stone was used in the interior?

Mr. Haggander: I think it is a limestone. It was not a very good grade of stone, not what we would call a very high grade of stone now.

Albert Reichmann, M. W. S. E.: I think Mr. Haggander's paper afforded us a very fine opportunity to compare things as they were probably before most of us were born. It shows the development that has taken place in the engineering field, in the construction of masonry work, and in the construction of our bridges; also, it gave us a little opportunity to observe the changes that have taken place in the transportation systems. I think the old bridge was figured for something like 2,200 pounds per lineal foot for a live load, and Mr. Haggander tells us the new one is figured for about 7,500 pounds per lineal foot. The old type bridges were built of iron, I imagine of wrought iron, and today our modern long span bridges are built of special grades of steel, such as silicon steel, and I know this bridge had heat treated I-bars. Instead of using a crude native stone, which was readily obtainable, we used a selected stone. We used the regular Portland cement in place of the natural cement. We used new pneumatic processes for going down to get proper foundations, so that it has been quite a nice picture to show really what has taken place in the way of progress in the last fifty years. I think we can be proud of the fact that we have made such tremendous progress in the arts in that time.

There was one thing I would like to call the engineers' attention to. That old swing bridge, while it was built a little over fifty years ago, still had some features in it of the present day bridge. That is, it was a center bearing and rim bearing bridge. We find that this type of bridge for long span, heavy construction gives very satisfactory results. We have built a number of very large bridges that way, and I think no one can find a bridge that will give better service than one using the combination center and rim bearing construction that Mr. Haggander has used in this bridge. In other words, we stick to the good things that are old.

Another thing that might be brought out was the modern method of erection used. We use no overhead gantry travelers any more, but use the derrick car or the traveling car of the derrick. We had no overhead falsework at all in putting up this bridge.

The Chairman: It seems to me that was a rather distinctive feature of this bridge; the use of locomotive cranes and derricks entirely.

Question: What was done with the old span?

Mr. Haggander: We scrapped one span 125 feet long. The timber was very badly worn; it was on a curve. We are still using all the other spans. In some cases we are cutting down the span lengths and squaring the spans up. That is, a 176-foot span will be made into a 150-foot span, squared up. By shortening the trusses say one or two panels we get a very good bridge that is strong enough for most of the modern engines.

Question: How did the natural cement stand up?

Mr. Haggander: It seemed rather poor. In the pivot pier, which was explored by making a tunnel, it was found that no progress could be made on account of the water, which had saturated the whole pier. The natural cement was not in first class shape.

Mr. Norwood: I would like to make a few more remarks. The motive power on the bridge is very simple. It is delivered at three phase, sixty cycle, forty-four volts. One 75-horsepower motor operates the whole bridge. The end lifts are operated with a high speed shaft about three inches in diameter with a system of clutches at the center which operates the toggles on the four corners through this shaft. From tests we made the power required to lift the ends was less than thirty horsepower, showing the great efficiency of those toggles. I remember when the toggles were assembled in the shop and were picked up by a crane and set on the floor they immediately collapsed. The workmanship was exceptionally good. The wearing parts of those toggles were of titanium aluminum bronze. They were very tough and very hard to machine. But it gives an excellent wearing surface, not only having to carry a certain dead load of the bridge and the friction of the moving parts, but also the live load.

The air plant consists of a fifty cubic foot directly-connected air compressor which furnishes air for the operating of the rail locks and for the whistle. We have a pipe line carried the whole length of the bridge with taps for blowing out purposes. The electric service was brought in overhead. I remember very well that these wires were strung in March. It had been an open winter, but the wind started early in March and often there were only three days a week that the men were able to work, due to the high volocity of the wind. There is a pivot switch on top of the bridge which transmits the current to the moving span for the power and for the various interlocking circuits from the signal tower, which is located on the south side of the bridge.

This bridge is the second installation that I know of that has an auxiliary equipment consisting of an automobile engine as developed today. We tried out one before on the Deering Bridge of the Chicago & Northwestern. The first equipment installed on the Northwestern was a 40-horsepower engine. This one was raised at 50-horsepower at a slightly slower speed. For auxiliary power nothing better could have been asked. All of the modern engine

accessories, such as governors, the gasoline feed and starting device, etc., were applied. At first, though the auxiliary equipment was looked upon rather skeptically, a demonstration of its practicability and durability for this class of service has made it a permanent institution for bridge work. We are now installing our sixth installation and have some more varied applications, such as certain jobs where we were unable to apply the gasoline engine direct, we apply the auxiliary power through a motor, the gasoline engine driving the generator. All the electrical parts, the rail locks, the centering device and the swing were interlocked, preventing the movement of any part until the previous cycle has been completed. The release of the bridge is given by the operator in the signal tower on the south end of the bridge, at which is located a storage battery plant, which furnishes power for the motor which starts the gasoline engine. The bridge also is equipped with the necessary navigation signals as is required on bridges on all navigable streams. There are practically no other lights provided except two in the operator's house, one in the watchman's tower immediately above, and some outlets for plugging in about the machinery. At each end of the roadway approaching from the north and the south sides, there is an electrically operated roadway gate controlled by the watchman on the upper deck. When these gates are closed he notifies the tower man, who releases the bridge operator so he can proceed then to withdraw the rail locks, lower the ends and swing the bridge.

J. E. Love, A. W. S. E.: It is quite evident that extreme care is taken to protect the wooden portions of the floor system from destruction by fire, but aside from the protection of the steel stringers by painting, has any attempt been made to protect them from gas and the probable effects of sulphuric acid or other acids which may be formed by the smoke from the locomotive? In other words, have the designers considered the use of a protecting plate of Armco iron or other material? Has any consideration been given to this point?

Mr. Haggander: We did give our consideration to it, but we did not see any very easy way of protecting the floor system from the blasts or from the gases. We thought we would do a little experimenting with different coatings of paint on the steel and see if we could not find something that would protect it. There is not much danger from the action of blasts up there, because it is nearly twenty-four feet from the top of the tie, but there is great danger from the gases. If we did put a protecting plate below the stringers I am afraid we would close the gases in there and keep them from going out. There is usually a high wind at this place and I don't think the gases will stay in there very long. We are hoping to protect that by different kinds of coatings. If anything has been found that will stand up under those conditions I would like to hear about it.

Mr. Love: Possibly you may recall the experiments made on the Santa Fe in regard to the protection of concrete surfaces. The

idea is to put a coat of paint which would catch the cinders and build it up by successive coatings of cinders and paint. That was as a protection for concrete.

Mr. Haggander: That is one of the methods we intend to try when we see how rapidly the present paint is going. We expect to have to paint that every two or three years for the time being until we get something that will last longer.

The Chairman: I notice that the piers were rather heavily reinforced with vertical bars. If the piers are mass section and not particularly high, particularly the portion that is inside the caisson and the cofferdam above it, I was wondering if the reinforcement is calculated as being necessary for possible stress or as a factor of safety?

Mr. Haggander: It is just a method of tieing the surface of the pier together—just a tieing together of the skin of the pier to prevent any cracks from forming, due to frost or any other reason. It is there to hold the pier together in one mass. There is no stress on those bars. It is a grid of one-inch bars, two-foot centers in each direction. On smaller piers we use three-fourths-inch bars.

The Chairman: Have you attempted anything along the line of piers not so reinforced? I mean in ordinary construction. Of course I realize that in a bridge such as this is, you are using concrete where in the past it was considered good practice to use only heavy stone masonry, but I have reference to piers in minor structures where you do not encounter the ice such as you did here.

Mr. Haggander: In some of our older concrete piers we do have a large number of cracks. I do not believe that it is due to any stress in the pier, however. It is merely due to the quality of the concrete and the local breaking up by frost, etc. Of course, there is some expansion in the piers. We are just hoping by this method to keep the pier from cracking and breaking up—just as you put temperature reinforcement in concrete structures; it is on the same theory.

Mr. Reichmann: I think it is very desirable to have all concrete structures that have to render any very great service reinforced. It takes care of the temperature stress, as well as any other stress that might occur. I think it is extremely desirable to have that reinforcement there.

The Chairman: I would like to ask Mr. Strickland how long the track was broken at the time the approach span was moved into place?

Mr. Strickland: That span was rolled in in less than two hours from the time we broke the track until we had traffic over it again.

The Chairman: That must have been a remarkable piece of erection. I understand from Mr. Haggander that something like two hundred trains cross that bridge in a day.

Mr. Strickland: That figure is about right. It took just a fraction over two minutes to perform the actual movement; the rest of

the time was consumed in jacking up the old span after the track was cut and lowering the new span on to the shoes.

The Chairman: The protection of the floor system from the brine drippings is something that has worried the railroad companies a good deal, and this method spoken of by Mr. Haggander seems to be a simple one to be so effective. To devise some way to protect the steel from the brine drippings has been the subject of much thought, and the way that Mr. Haggander has mentioned is certainly something to be welcomed by all the railroad lines.

Proceedings of the Society

Meeting No. 1029, February 3, 1919.

This was a general meeting of the Society and was attended by 127 members and guests.

Prof. H. H. Stoek, University of Illinois, presented a paper on the "Mining Resources of the War Zone." This paper was illustrated with lantern slides and statistical data of the mineral resources of England, France, Belgium and Germany under pre-war conditions.

Meeting No. 1030, February 10, 1919.

This was a meeting of the Bridge and Structural Engineering Section and was attended by 64 members.

G. A. Haggander, bridge engineer, C. B. & Q. Railroad, presented a paper on the "Design and Construction of the C. B. & Q. Railroad Bridge Over the Missouri River at Kansas City." This paper was illustrated with lantern slides.

K. L. Strickland, directing engineer, American Bridge Co., discussed the paper and presented slides, showing the erection features.

Meeting No. 1031, February 17, 1919.

This was a meeting of the Hydraulic, Sanitary and Municipal Engineering Section. Attendance, 37 members and guests. Linn White, chairman of the section, presided.

Maj. Leonard S. Doten, construction division of the U. S. Army, presented a paper on "Sewerage, Sanitation and Reclamation at U. S. Army Camps." This was illustrated with lantern slides. Special attention was given to the sewage disposal plant now being erected at Fort Sheridan.

Meeting No. 1032, February 24, 1919.

This was a joint meeting of the Electrical Engineering Section and the Chicago Section, A. I. E. E. There were present 180 members and guests.

John B. Taylor, consulting engineer, lighting department, General Electric Company, Schenectady, N. Y., presented a paper on "Acoustical Engineering." This paper set forth the principles of sound and the development of acoustical apparatus, including the reproduction of sound by phonograph and the scientific analysis of the human voice and musical instruments.

Refreshments were served.

EDGAR S. NETHERCUT, *Secretary.*

Book Reviews

Handbook of Hydraulics, for the Solution of Hydraulic Problems. By Horace William King. First edition. 424 pages, 4 by 7 inches. Many illustrations, diagrams, tables, etc. Bound in black leather and published by McGraw-Hill Book Co., Inc., New York. Price. $3.00.

Our immense water power is being developed rapidly, as those of our readers who have followed the subject are well aware. The mere presence of running water in a district, however, does not mean that commercial water power can be economically produced. There must be a knowledge of the amount of water available throughout the entire year, as well as other economic facts. Without accurate data one might easily install equipment which would be idle part of the time, or which would at no time ultilize all the available energy.

This book aims to give the reader, or the engineer or student who already knows the rudiments of hydraulics, the methods of determining the available energy of a stream. It aims to harmonize theoretical considerations with practical problems, to simplify hydraulic computations and to secure greater practical accuracy. Various formulas have been suggested heretofore, and the hydraulic engineer is familiar with the experiments, deductions and formulas of Kutter, Manning, Lyman, Bazin and others. Each of these scientists evolved from experiments formulas which are accurate within the limits of certain conditions. The author compares the various formulas, suggests limitations, and adds a vast amount of information on the subject of Hydraulics generally.

It will be of interest to know that the subject matter is divided into chapters on Hydraulic Units, Hydrostatics, Orifices, Sharp Crested Weirs, Weirs not Sharp Crested, Flow of Water Through Pipes, Flow of Water in Open Channels, Measurement of Flowing Water, Special Problems, General Reference Tables, and Comparison of Weir Formulas with Experiments and Comparison of Kutter, Manning and Bazin formulas with Scobey's experiments. Tables to the number of 112 are given, all of them of value to the hydraulic engineer.

Practicing engineers, as well as students, will find in this book a handy compilation of the data, formulas, tables, etc., required for the practical study and practice of Hydraulic Engineering.

Relief from Floods, The Fundamentals of Flood Prevention, Flood Protection and the Means for Determining the Proper Remedies. By John W. Alvord and Charles B. Burdick. First edition. 175 pages, 6 by 9 inches. Illustrated by photographs, drawings, diagrams, tables, maps, etc. Bound in cloth and published by McGraw-Hill Book Co., Inc., New York. Price, $2.00.

Vast areas of the most desirable land being more or less subject to floods makes the subject of flood prevention and control a most important one. Among leading engineers it is recognized that excessive rainfall can be carried off without destruction of life and property, provided that suitable provision is made before the flood comes. The study of the cause of floods naturally suggests the possible remedy.

When the last great flood visited Ohio the authors of this book made a comprehensive study of the entire situation and their observations and recommendations are referred to more as the method of dealing with a particular problem than indicating a method of procedure for all problems. Other situations might be remedied by some of the other methods suggested. Careful study must be made before any plan can be suggested. Thus, a mountainous country, like Colorado, requires different treatment from a flat country like Louisiana. Data must be collected for years, for it is noted that the greatest flood of the River Seine in Paris occurred 260 years ago,

the greatest on the Danube 400 years ago, and our own Mississippi had its greatest recorded flood 130 years ago.

Some idea of the valuable material collected may be indicated from the chapters on The Food Problem, Various Means of Relief, Flood Investigations, Fundamental Data, Future Floods, Flood Protection by Channel Improvement and Flood Prevention by Water Storage.

The book will be of value to the broad minded man who wishes to secure all possible information on this subject. It will give an excellent starting place for future flood prevention, investigation and work.

The Principles of Wood Ship Construction. By W. H. Curtis. First edition. 223 pages, 6 by 9 inches. 199 figures and illustrations. Bound in cloth and published by the McGraw-Hill Book Co., Inc., New York and London. Price, $2.50.

Wood ship building, while practiced to a limited extent, was almost an unknown trade up to a few years ago. As wood ships unquestionably had advantages, great efforts were made by the Government to increase their numbers during the war. Previous to the war a considerable number of ship yards were busy on this construction, especially in the West, where the forests made lumber quickly available.

While the requirements of the various Classification Societies were well known, these referred more to materials, sizes, etc., rather than to workmanship. There was a great need, therefore, for a book like this, which shows in great detail the methods of construction of practically every part of the wood ship, for the use of carpenters and others who, though skilled in their work, lacked the knowledge of details of ships necessary for the most efficient performance of their work in the yard. The numerous drawings have been specially prepared with this thought in view, and cannot fail to be of value to the draftsman and designer as well as to the carpenter, foreman or superintendent.

Under the various headings of Keels, Stems and Stern Posts, Frames in General, Inboard Hull Details, Deck Details and Planking Sections and Joiner Work, practically every feature of the subject is treated in detail. The illustrations, as well as the text, are readily appreciated by practical carpenters, and will settle many of the arguments and questions arising regarding procedure and methods. C. A. M.

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Electric Welding as Applied to Ship Building

By COMFORT A. ADAMS,
President, American Institute of Electrical Engineers

Presented December 30, 1918.

THE first work done in the application of electric welding to ship building was under a sub-committee of the standards committee of the American Institute of Electrical Engineers. That work began early in August, 1917, and was carried on for two months. It was adopted by the general engineering committee of the Council of National Defense. During the early part of 1918 the Council of National Defense disbanded practically all of its technical committees, advisory committees and turned them over to the industry. We then got into contact with the Emergency Fleet Corporation and the committee was adopted by it. Since that time it has been operating as an official committee, aimed largely at research work, which is intended to develop the degree in which electric welding may be applied properly to ship building.

The committee on electric welding for the Emergency Fleet Corporation consisted of about 140 members, including some of the ablest welding experts in the country, some of the ablest metallurgists in the country, some very able physicists, electrical engineers of broader training, representatives of the Emergency Fleet Corporation, including some of their best naval architects and outside naval architects, naval constructors, representatives of the Bureau of Standards, a representative of the manufacturers of electrical welding apparatus, and finally we have taken in the gas welding industry in a body.

In the early days of this committee, the Emergency Fleet Corporation came to us asking for help in new methods or improvements in anchor chain production. The production capacity of the country at that time was about 15 percent of the demand. Anchor chain may seem a small thing, but when one realizes the number of tons of anchor chain on each ship, it will loom up into quite an appreciable factor.

In two months we had developed a cast steel anchor chain. Previous to that time anchor chain had been made in the same way for generations. Bars were cut, bent and welded, and then forged. Some little improvement had been made in large chain by using a

drop forge, but for the most part the same slowness was involved, the expense was great and the chain, when produced, was really not of the quality which was desirable. In spite of the fact that when we cast our first cast steel anchor chain the conservative ones, the old industry representatives, insisted that the old wrought iron chain was just what they wanted, they agreed with us after six months of education, it having taken two months to develop the steel anchor chain and six months to educate the conservatives, the ship builders, navy, classification societies, United States steamboat inspection service, etc.

The classification societies, the American Bureau of Shipping, etc., accepted that chain and adopted test specifications. The test specifications are just 40 percent higher than the old wrought iron chain and there is still a margin above that.

The Emergency Fleet Corporation finally commandeered the new plant of the National Malleable Castings Company at Cleveland, Ohio, which was designed for malleable castings in general, and turned it over entirely to anchor chain production, and that one plant can produce all the anchor chain that the world needs. The chain is cast all in lengths without any welding at all. There are a dozen different molding propositions, but they have not been sifted out as yet in order to find which is going to prove the best commercially. The type of steel used is the Naco steel, which is the same as that used for the knuckles of the car couplers. It is a relatively high manganese steel, heat treated very carefully.

The two types of electric welding which are employed for ship building are arc welding and spot welding. Arc welding consists in striking an arc between an iron wire and the joint between the two plates, which has been prepard for welding. The arc is struck between the wire and the joint down below, the wire is drawn away, and the arc lies between the electrode and the plate. The lower end of the arc on a plate fuses in; this metal is fused and passes across the arc to the plate. I say "passes across" rather than drops across because you can weld up overhead as well as underhand.

The actual phenomena involved in the passage of the metal across the arc are not wholly known or understood. We have some very interesting experiments going on and there are a number of theories in regard to it. In some cases we know the arc is drawn too long and the metal does actually drop across, if you are welding down hand instead of overhead, but overhead the metal gets there just the same, no matter which the direction of the current, or whether it is direct or alternating current. The electrode is moved back and forth and the space is gradually filled up. If the plate is a thin one, the filling can be done in one layer, but if the plate is half an inch thick, for example, it is desirable to lay it in in two layers, making two runs, as it were. Sometimes a large electrode and a heavier current is used for the upper run.

When the joint is filled, it is usually filled up rather full, a little bit above the line plate. The variables which enter into the

success of the weld are numerous, so numerous that the number of tests which must be made in order to eliminate these variables and trace them down to their lair, as it were, to find out exactly what is the importance of each one, is enormous.

For example, we have approximately twenty tons of plate cut up into small samples in process of test at the present time. Most of our tests have been made upon half-inch plate but we have some three-quarters and some one-inch plate. The details are numerous but I am going to mention one or two of the vital factors.

In the first place the composition of the plate itself, not only chemical composition but its physical quality—the grain or size of crystals in the plate—depends upon the (1) physical treatment or heat treatment, (2) the composition electrode and its physical condition, (3) the current and the size of the electrode with relation to the thickness of the plate, and (4) finally, the operator. The regulation of the current is more or less automatic by the supply of current—that is, by the system employed in its supply.

Those, roughly, are the major factors in the success of making a weld of this sort. There are some matters in regard to details of the preparation of the joint which have to do with the practicability of the weld.

The skill of the welder is one of the most vital, and most important points of the whole proposition. The most important factor in determining the success of the weld and the skill of the welder comes in in some such way as this: You have a short arc. The area of a spread down at the bottom is small and the temperature of this plate or the density of the actual energy dissipation at this electrode per square inch is higher than it would be if you had a long arc where the arc spreads, or, if it contracts a bit at the bottom, it wanders about a little so that it actually covers a larger area.

That is an explanation of the theory that the long arc does not make a good weld. You do not get an actual fusion of this plate so that a real bond takes place, and also because the long arc with the bare electrode has greater opportunity for ossification in passing across.

There is another variable which I have not mentioned, namely, that some of the electrodes are flux covered. That is, there is a layer of flux of some kind or variety on the outside and that flux in fusing frequently forms an envelope, sometimes a gaseous envelope. The best known flux covered electrode in this country is asbestos iron with a little electric iron for producing agent and some salts mixed in with the iron. The asbestos, fusing, forms a molten slag or molten envelope around the arc so that it protects the arc from oxidation. That is one of the chief claims of the manufacturers.

But the bare electrode costs from eight to twelve cents a pound and this particular type of flux covered electrode about seventy-five cents a pound with actual welding wire. Without going into

these variables to explain their importance in detail, I will simply say that one of them, i. e., the type of current regulation, is dependent upon the inherent regulating qualities of the operatives back of the current, which is a matter of comparatively small importance. Manufacturers of each type disclaimed, when we first entered the field, that their success was due wholly to the particular regulation —the most accurate regulation—of their apparatus. We made tests on half-inch plates, all taken from the same material, prepared in the same way, welded by fifteen different manufacturers, who picked their best men, their own electrodes, everything just as they wanted to suit themselves, and we could detect no consistent difference between those various types. There was no consistent difference between the bare electrodes and the flux covered, between direct current and alternating current and the average on all those tests, over a hundred samples of fifteen different makes, was about 94 percent of the strength of the plate. Half a dozen or more broke outside the joints when tested and there were no low ones. They were all up.

There is another quality, however, of the arc weld which in some cases is perhaps as important as the tensile strength, and that is the ductility, which in some degree is a measure of the shock resistance or fatigue resistance strength of the joint. In a ship there are vibrations of all kinds and it is important that the joints be such as to resist these vibrations of low intensity as a rule, but still keeping up continuously, running into the millions in the life of the ship. Tests are now being carried on to determine the relative fatigue resisting qualities or fatigue enduring qualities of these different types of welds.

To give you some idea of the tensile strength of the joints and some of the factors on which they depend, I will state that as between different compositions of electrodes from practically pure iron, the Armco iron, as it is called, which has about .16 percent total endurance, and an ordinary milled steel wire, both in proper physical condition and both handled with the proper current and operator, there does not seem to be very much difference in the resulting weld. In other words, there is not the same connection between the tensile strength of the weld and the tensile strength which goes into the weld as you may imagine.

The actual tensile strength also seems, for some reason or other, to bear relation to the plate, because with the mild steel plate such as used for most ship work you get tensile strength up in the vicinity of the strength of the plate itself, we will say, running from forty-five to sixty-five thousand pounds per square inch; whereas the same electrodes, employed on welds of high carbon destroyer plates with much higher tensile strengths, have some tensile strains from seventy-five to eighty-five thousand pounds per square inch.

I am merely telling you some of these facts which may interest you as indicating the immense field for exploration. Some explana-

tions have been given of these facts but they are not such as to warrant any announcement. One thing we found out in these early tests was this: We did not find consistent differences between the electrodes, between the machine current control, between the bare and the flux covered electrodes, but we did find a consistent difference when the strengths and ductilities were plotted against the current strength, and we found on the average, going through points which scattered around very much, plotting the length of the tensile strength and the current strength, that there was a definite upward trend up to a certain point, that the upper range of the current value actually used as compared to the lower range was a difference of nearly thirty percent.

That was the only consistent difference we detected. Actually, most of the users of this welding apparatus used it away down below the best point, and that superiority was not only in tensile strength but also in ductility. There is an upper limit but a great many things enter into that and I am not going into any detail.

So much for the picture of what arc welding is and what it does. Now, as to the apparatus. That can be almost anything—water buckets, proper adjustment of plates in series of 110 volt circuits, either direct or alternating current or reactant, if 110 volt alternating current supply is sufficient to cut the current down to the proper point. It will make perfectly good welding with a good operator, but the resistance, since there is the direct current (of course you can not use reactants there without resistance also) is about 20 volts with the bare electrode, absorbs so much of the energy that it is inefficient, so it has been customary in this country to a very large degree to use motor genitor sets, the genitor having a lower voltage for a direct current. This voltage ranges from forty up to sixty, depending upon the theories of the manufacturer, adjusted for approximately constant current. As the operator varies the length of the arc he can not keep it perfectly still; as the arc length varies the machine automatically keeps itself properly concentrated.

One of the troublesome things about arc welding is the burning of the skin if it happens to be exposed. The face and eyes particularly have to be protected by colored glass, and the hands have to be protected by gloves; otherwise, one gets seriously sunburned and the eyes are seriously affected. It does not take very much to protect the eyes. Using plain glass, except for intensity of the rays, shuts out the ultra-violet rays.

The relative cost of arc welding apparatus from the supply mains will run anywhere from a hundred dollars with a simple rheostat, 110 volt circuit, to ten or twelve hundred dollars with motor genitor sets. The efficiencies are not nearly as widely varying in range as one might imagine, because the small motor genitor sets have only an efficiency of 50 percent when they are running full load and the operator does not keep the arc running steadily

all day. He is running only about half of the time and consequently the motor is running light and you have light load losses.

Also, the transformer loss, due to the heavy leakage, is high; efficiency is low, and the heavy current in the primary low power factor is another cause for losses all through the system.

There are claims made for very much higher efficiency in some cases than in others and the alternating current apparatus doubtless does, as far as the alternating current itself is concerned, have a higher efficiency than any of the other types of apparatus.

SPOT WELDING

Arc welding requires an apparatus that you can hold in your hand and use in any nook or cranny; spot welding requires another apparatus. Spot welding consists in gripping two overlapping plates between the jaws of a device very much like a bull riveter. These are the electrodes and the terminals have a low voltage transformer. On high voltage we use a 20 to 25 ton pressure, and current is passed through these leads, thirty to forty thousand amperes at about three to three and a half volts between electrodes. The weld is made at the point between the plates, because that is the point of least resistance. The time has to be adjusted with reasonable accuracy but varies with the current obviously.

Spot welding requires less labor, less time and more power than arc welding. That is, to make a spot welding joint of given strength, make a number of spots along and by putting in a double row such as a double row of rivets, you could easily make the weld stronger than the plates. In riveted joints you must cut out a part of the steel, which weakens the plate, so the joint is no stronger than the remaining section of steel left in place, whereas the weld does not do that in any case.

The reason for the weight of the spot welder is two-fold. In the first place, you must have a very heavy pressure and if you must make a gap in your welder to straddle a six-foot plate and have twenty-five tons pressure at the end, you get some idea of the size of the structure. Moreover, you must have a transformer for welding half-inch plates, which has the capacity of approximately four hundred kilowatts; and, while that can be designed with low voltage, very compact, with water cooling as a secondary, the style means something and a water welder, if you could make one portable, could hardly be built weighing less than three tons for welding half-inch plates.

So, it is not a little thing you can hold in your hand; it is a heavy instrument that you can not get into all the nooks and corners; it is limited in its application, but in many parts of the ship's plates, if you can get the welder to the spot and carry it around and adjust it, the spot is easily welded.

That, roughly, constitutes the limitation of the spot welding. The power required is another limitation; that is, it cannot be used on a small plant. It requires a plant with power enough to furnish

this power without disturbing the system. The method of overcoming that difficulty is to have a motor genitor set with a very heavy fly wheel, genitor end being single phase. That equalizes the load on the phase and also equalizes the load on time, so, if you place these with twenty second intervals between, a fly wheel can be made large enough to carry you across and wipe out the sudden fluctuation.

When we come to the actual application of this work to ship building, we meet with the same old obstacle of conservatism and the roots of an old, established industry, and we have as the chief watchdog, the classification societies, without whose rating you cannot get the ships to show. Consequently, it is necessary for us to court the classification societies and one of our most active members is a high official in Lloyd's Registry of Shipment.

The first thing we did was to get the approval of the classification societies on arc welding on minor parts of a ship. By minor parts I mean such things as hatch combings, ventilators, boundary angles, etc.—a lot of the minor parts and attachments all over the ship. Over a half million of those parts were being built for certain types of ships being erected at Hog Island alone, so their importance is nothing negligible, although they are minor, not strength members of the ship.

The growth of welding as applied to these minor parts of a ship has been comparatively rapid in newer, larger yards; in some of the older yards they were slow to take it up. At Hog Island they are doing welding in very considerable quantities. The Great Lakes Engineering Company at Detroit are pushing their welding department very rapidly, developing it now at a very rapid gait. In fact, they employed a welder there they stole from Newport News, where they have been doing welding for a long time on navy work, paid him sixty-five dollars a week, and a couple of weeks after he arrived he wanted five thousand dollars a year and his expenses. He was a good man, but that will give you some idea of the demand for really first-class welders.

I spoke of the cast steel anchor chain. Now, we are talking about a cast steel ship. As a matter of fact, a company has been formed called "The Cast Steel Ship Building Company," the idea having been originated by Mr. Hill, a member of the committee. He has designs complete, so as to reduce the number of types of castings, eventually worked out types of castings in the foundry, and he can cast half-inch plate perfectly successfully.

Moreover, he casts the frame on the inside of the plate in sections so that it is not welded on, but the sections of the plate and frame are welded together and you can thicken it up at the edges so as to make the weld cross section heavier than the plate, which will be an extra factor of safety at the joint. The whole thing is interesting; it is not at all a wild, hare-brained scheme but is something to be duly considered. Problems have to be worked out as with any new thing of this sort, but it is entirely possible that this

may develop into the most economic type of welded ship, and a very great saving is claimed for it.

Finally, while I don't wish to make any prophecies, I am going to merely repeat what one of the highest naval constructors in the navy said to me not long ago. He said, "While we are conservative, we want to go slowly on this work and be sure we are all right, we are nearly all of us convinced that the welded ship is the ship of the future."

That is not only my personal opinion, but it is the conviction of practically all of those who have been concerned with this work. The problem before us now is not only to complete this research work that we have carried on to reduce all the variables to a definite known basis, to be able to tell exactly what the importance of each is and exactly how to adjust each to get the best results, but also to try and interest the ship builders to the extent of finishing this work to the practical limit in order that we may meet competition in this field. Unless we can adopt every possible economy in ship building in this country, it is absolutely impossible for us to compete with England, to say nothing of Germany and other countries, in the ship building field.

Now, our merchant ships during the war (of course things were excessive, then) cost us $200 a dead weight ton or more to complete. England offers now to build all the ships we want at a hundred dollars a ton, dead weight ton—just half of our cost! England is pushing this work, she has followed our lead as far as the committee is concerned, has a large committee under the Admiralty (the Admiralty there controls both the navy side and the merchant ship side) working along similar lines.

There is just one other piece of work that the committee did in experimental lines which is rather interesting. They built a twelve-foot cube tank of half-inch steel plates, joints were regular ship joints of thirteen different varieties. It was filled with water, pressure applied at forty-three pounds per square inch before a seam opened. Now, when you get a tank twelve feet square to a side and forty-three pounds to the square inch, a little arithmetic will give you some idea of what the tank's joints are.

We secured much information as to the cost of making these long welds, avoiding contraction strains, warping, etc., but I wish I could tell you that we are going to build a welded ship. There is no immediate sign of that, although one ship builder will be glad to undertake it as soon as he can get somebody to order one, and other ship builders are interested in it. In fact, I think it is altogether likely that Mr. Schwab will tackle the job himself. Before the war stopped he had promised me that he would authorize the building of a completely welded ship, but that was two days before the armistice was signed and he was so anxious to get out. When he got through, he said he would have to let it go over to the others who were in authority after he left, because he could

not put it through at that late date, because the others would cancel it; they feeling much more conservative about it than he did.

DISCUSSION

C. H. Norwood, M. W. S. E: Is there any preparation of the surface of the metal necessary in welding as to treatment or cleaning?

Mr. Adams: In the joint between the plates any ordinary corrosion is not troublesome. If the layer of rust is so thick as to actually choke off this low voltage current so it cannot get started, then it is necessary to clean it off, but any ordinary corrosion on plates does not bother because the higher that resistance, the greater the heat developed in there and the slag throws out all the dirt. In fact, you can have it greasy if you like as long as it is not too thick a layer, but under the electrodes, under the outer surface of the plate where the electrodes come in contact with the plate itself, it is necessary to have a fairly clean surface; otherwise the resistance there will be so high that too much heat will be developed under the electrodes and they are apt to fuse on to the plate. The water cooling will prevent that ordinarily.

J. E. Freeman, A. W. S. E.: In what one of the concrete ships, or in what several concrete ships under construction is this welding apparatus being used in butt welding the reinforcing bars?

Mr. Adams: As far as I know, very little welding was done on any of the concrete ships now in use. Under construction, some experimental work was done both at arc welding and spot welding. I am pretty sure that no concrete ship has been built in which all the reinforcements were welded.

Mr. Freeman: Do you know what the area of the weld was, cross sectional area, as compared with the area of the reinforcing bars themselves in these tests that were made?

Mr. Adams: The corners were put together and mashed in about a third of the way through. We tested them repeatedly but every time the bar broke and the weld held.

Mr. Freeman: You spoke about the cost of the construction of welded steel ships in England as being a hundred dollars a ton.

Mr. Adams: That was just the complete merchant ship built today—a hundred dollars per dead weight ton. Dead weight ton means roughly the carrying capacity figured on a volume basis.

A. W. Leach: May I ask what provision was made to dissipate the end currents in the spot welding apparatus? Is there not a great deal of loss in heating?

Mr. Adams: In the single circuit machines there is, but it is small when it comes to the total amount of power applied. Those leads are comparatively short. In the double circuit machine the eddy currents are very much reduced, the two circuits are side by side. Even in that case you can easily make one of those things so as to have a very high reaction.

Mr. Leach: What I thought was that the leakage flux would flow around completely through the weld and around the welder.

Mr. Adams: Of course any currents in welding are not objectionable. They contribute to the heat. There are phenomena about a spot weld which are very interesting and subject to careful analysis but they are not significant in quantity as yet. If anyone could devise a double circuit machine like the one I showed you, without danger of shunting much of the current between two electrodes through each of the plates, it would be quite a step in advance but you would be surprised to find that a little is shunted in there—I mean how much goes directly through the spots. The plate is heated between the spots more than it is around the spots. You can see that, the glow is dull red, but not nearly as hot as in the spots themselves. That is a great drawback to the spot welding.

W. E. Williams, M. W. S. E.: Where two long plates are connected together, commencing at one edge and running across, does that produce a buckle in a plate?

Mr. Adams: If it is all filled up at one layer it would. There are two ways of doing it. Some use what they call a non-rigid system, leaving the plates open at the end, start in welding at this end and then gradually get up to the other end. That is not possible in a fabricated ship where you have the pieces at right angles to each other.

Mr. Williams: In welding a corner, is not the size of the wire or rod you use a serious factor in controlling the current to fit down into a corner? It is my experience that when you get into a corner the arc wants to jump off to each side rather than go down into the corner.

Mr. Adams: That is one of the chief advantages of the flux covered electrode. Then you can get down into that corner very much more easily.

Mr. Williams: I tried a scheme of a current of air to direct the arc down the way I wanted it to go, but the air would not go there either. Again, there is the relative cost of making the seam as you have indicated by the arc system or by the spot welding system; which is the cheaper?

Mr. Adams: If you have a simple, straight-away seam that you can handle easily in one of those big stationary spot welders, just an overlap between two plates, a spot welder saves so much more labor that the extra cost of power does not count.

Mr. Williams: If you spot weld a seam, say thirty-six inches wide and eight or ten feet long such as might be crowded into the end of a steel car, would the spot weld meet the rivets and the arc weld in cost?

Mr. Adams: Absolutely! You put your spot welds in approximately the same as rivets. A single row of spot welds is better than a single row of rivets. In that quarter inch material you can

make those welds in five seconds and run along there and spot almost as rapidly as you can put rivets in.

Mr. Leach: You spoke of the flexibility and brittleness of the steel. In the hard or highly tempered steels what was the action of the heating, particularly in the butt welding, in taking the temper out of the steel immediately surrounding the weld?

Mr. Adams: This is all-mild steel that I am talking about here.

Mr. Leach: You spoke one time about some highly tempered steel, did you not?

Mr. Adams: I said high carbon steel, not tempered steel—just destroyer plates.

Mr. Leach: What would be its action on highly tempered or hard steel?

Mr. Adams: It has been used for practically all kind of steel but just what the effect is upon the hard steel I couldn't say. Obviously you aren't going to get the same quality.

Mr. Leach: Do you think it might be a detriment in hard steels in making those welds?

Mr. Adams: It depends upon what you wanted the weld for. Suppose you want it for that very purpose, you want to weld and still maintain the hard steel. They have welded high speed tool steel from a high speed steel tool electrode on to a softer shank and then used it to cut with. The tendency of the weld is to be thoroughly hard. It is a very difficult matter to get a weld that is very soft. You have to put it on in thin layers to get the leaning effect of the body around it and most welds that have been made have been made with flux covered electrodes.

Mr. Williams: If you were to join two plates together and spot weld them in the middle or at each end, would you not be able to arc weld the remainder without a buckle, taking separate points?

Mr. Adams: Yes, provided you make the intervening weld by several light layers. We can make that all in one heat, fill it up all in one run. The amount of spreading of heat is so great that in some cases the welds have been known actually to crack themselves.

Mr. Williams: I have tried instantly cooling the surface immediately following the arc but it was an ineffectual test.

Mr. Adams: Many of those long arcs have been welded without any bad results at all, in fact with perfectly good results with the tacking process. That is, the plates placed at top position, tacked at intervals and then filled up, and it is preferable to run a short Bartlett weld at frequent spaces, not running continuously all the way across but rather in pieces here and there so as to keep the temperature of the plate, as a whole, down.

Mr. Leach: You spoke of the tensile strength; how about the crushing strength?

Mr. Adams: That is ample, it is away up. There is no difficulty there, the joints never crush.

Mr. Leach: And their torsional strength?

Mr. Adams: Yes, we have made many torsional tests. A torsional test is little more than a ductility test.

A. Herz: Have you been successful in making seams in cast iron?

Mr. Adams: The cylinders on the German ships were cast iron; and the worst I have ever seen.

Mr. Lorenz: In your experiments have you discarded the carbon electrode in favor of the metallic electrode for all classes of work you are doing on the shipbuilding?

Mr. Adams: No, it has not been discarded. It has not been adopted. It is purely a negative attitude. It was the assumption by practically everybody connected with the committee based on their experience when we started that the metal electrode was the thing and it is only recently that some experiments with the carbon arc have been made.

Mr. Lorenz: We have found in some of our practice that preparing a weld with a carbon electrode and filling with a metallic electrode gave us very quick results. We can preheat so much quicker with a carbon electrode and filling with a metallic electrode gave us very quick results. Some of the work, a hard weld, as produced by a carbon electrode is objectionable and changing it over to the metallic electrode after you have prepared your spot for welding gives very superior results, yet we are using all types of machines and even the old water resistance welder, from which we are getting good results; but as you say, the operative, in a great many cases, seems to determine the efficiency of any weld. We find in some cases where a man is very anxious to clean out a place and weld it they have gone so far as to take a carbon electrode and fuse the spot, get it in a condition for welding; there might be a little slack or dirt in there and they would stick the carbon electrode in there and splash it around to get it out. You can see there would be a high carbon deposition right there in that weld and it would be practically worthless, so for that reason we felt the metallic electrode was the better of the two schemes of welding.

Mr. Adams: We are so used to hearing of cases of unsatisfactory welding that it is no surprise. We know what the trouble in most cases is—with the operator—that there is as much difference between a good operator and an ordinary operator as there is between day and night. The ordinary operator may do fairly good work for expert purposes where the ultimate quality, the maximum attainable quality is not necessary as demanded by the work such as odd jobs around a shop. Even on work on Liberty motors, there are sections where there is no particular strain on the part at all. It means merely to fill up a gap and tack two pieces together. That is easy enough and men get in the habit of thinking, "Oh, I learned to

do this work in three days," but you can not train a welder to do the things I have been talking about in three days or three weeks.

Mr. Lorenz: In regard to the work that is being done by the committee—will there be any public reports made on it so that we can get in touch with the work? It seems to me that the work which has been done is of vital interest not only to the ship building industry but to practically every other metallurgical line in the country and it is a live subject, you will find, with most of the manufacturers today. We are all anxious to get the latest information. As a matter of fact, people who are interested in welding—that is, electric versus gas welding, etc., are almost at sea to get reliable data as to costs and methods and results obtained. If we could get that information I think it would be most acceptable.

Mr. Adams: We had some hard work in getting information on gas welding. Manufacturers did not have any. We told them that for the straight away quantity work on a ship, gas welding cost about twice as much as arc welding and they were going to disprove it the next day, but they did not disprove it the next three months.

Effect of Metering on Water Consumption

By H. P. MATTE, A. W. S. E.,
Chief Sanitary Engineer, Illinois State Department of Public Health.

Presented December 16, 1918.

IN considering the effect of the installation of water meters upon the consumption of water, and in comparing the usage in various cities, three elements, which may have an important bearing upon the results, are seldom taken into account. These are:

1. Pressure upon the water system.
2. Extent of house connections with sanitary sewers, especially the use of bathtubs and water-closets.
3. Effective size of mains and services.

PRESSURE ON WATER SYSTEM

When per capita rates of consumption are published or mentioned, how often is the average pressure at which the water is supplied included? It is a mistake to omit that item, as it is an important one. A city with a high pressure will find that its leakage rate, both through fixtures and underground piping, will be greater than that of another city which maintains a lower average pressure.

In Oak Park the per capita rate of consumption is easily varied between one and two gallons per pound change in pressure within the entire range of rates of consumption. That is to say, 10 pounds' variation either way will make a difference of 10 to 20 gallons per capita daily. Thus the Oak Park rate of 65 gallons per capita at 45 pounds' pressure can be reduced to 45 gallons at 25 pounds. In Niagara Falls, where the per capita rate of consumption was 300 gallons per diem, exclusive of the industrial usage, the writer determined this rate to be from 3 to 5 gallons per capita per pound change in pressure, or 30 to 50 gallons per capita for each 10 pounds. The Niagara Falls consumption was about 6¼ times that of Oak Park and the average pressure was about 60 pounds, which accounts for the different limits; but the principle is the same and its importance is clearly seen. The pumping units were designed for a maximum rate of consumption owing to the heavy drafts, and as there were no small units provided, the effect of reducing the fixture leakage by the installation of meters and the house-to-house inspection was to boost the pressure at night some 30 pounds greater, or to 90 pounds; and the effect of reducing the leakage was not evident owing to the greater discharge of water through the remaining defective fixtures.

The following table shows one of the uses of water affected by pressure:

A ¾-inch hose 50 feet long with nozzle—

At 60 lbs. consumes 5,000 gallons per day if in form of jet.
At 30 lbs. consumes 3,600 gallons per day if in form of jet.
At 55 lbs. consumes 10,000 gallons per day if in form of spray.
At 30 lbs. consumes 7,200 gallons per day if in form of spray.

These figures have been obtained from tables prepared by Manager Sullivan of the Nashua (N. H.) Water Company.

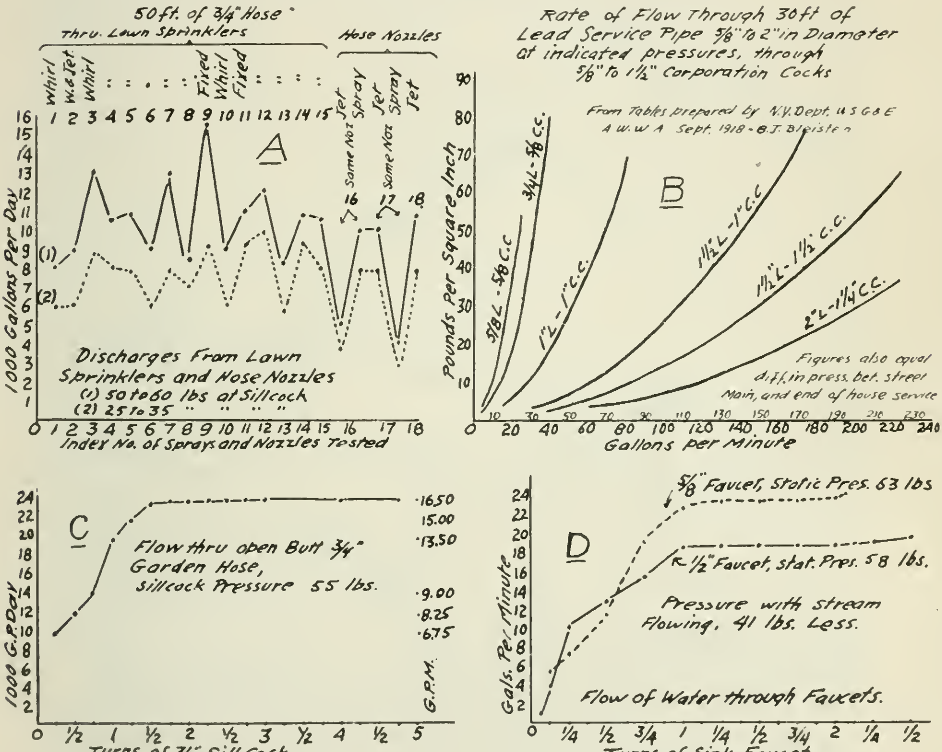


Fig. 1. Diagrams Showing Rate of Flow from Statistics Prepared by W. F. Sullivan, Superintendent Water Works, Nashua, N. H.

EXTENT OF CONNECTIONS WITH SANITARY SEWERS

Another element which is noteworthy in its effect on water consumption is the use of water-closets and bathtubs. Although the number of consumers on the line of pipes are often considered in computing per capita consumption, it is seldom that the number of consumers which have the use of faucets only are separated from those which have all the sanitary conveniences.

In Oak Park, from numerous experiments, we determined that the average number of gallons per capita consumed by water-

closets where no leaks or waste existed was 20; while under the same conditions the average family consumed 15 gallons per capita through bathtubs. An interesting fact connected with the use of bathtubs is that a person who takes cold baths every morning is very likely to consume 40 gallons per day in this item alone. A psychological effect of the lack of pressure, consequently an increase in length of time required to fill bathtubs, oftentimes reduces the quantity of water used for baths.

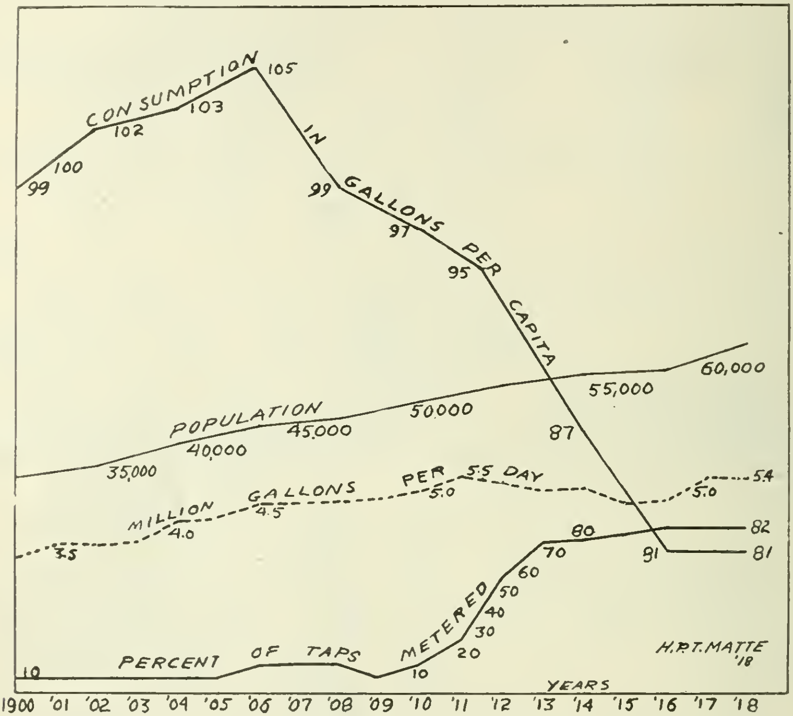


Fig. 2. Diagram Showing Population, Consumption of Water and Percent of Services Metered in Springfield, Ill.

The records from the following cities show the effect of the installation of sewers upon the general water consumption:

City	Before installation of sewers	After installation of sewers
Marlboro, Mass.......	21 g. p. d. per capita	38 g. p. d. per capita
Newton, Mass........	31 g. p. d. per capita	63 g. p. d. per capita
Waltham, Mass.......	32 g. p. d. per capita	70 g. p. d. per capita

In Madison, Wis., the per capita daily consumption in residences with sewer connections was 68, while in residences without sewer connection it was 14.

In Rochester N. Y., services with water-closets consumed 22 g. p. d. per capita; services with water-closets and baths, 18 g.

p. d. per capita; services with water-closets or baths, 14 g. p. d. per capita.

The limited extent of services and sewer connections in foreign cities, thus cutting down the number of outlets for consumption and fixture leakage, is responsible for the low per capita consumption in those cities. From figures obtained three or four years ago it was noted that the large European cities of over 2,000,000 population had about as many service connections as the average

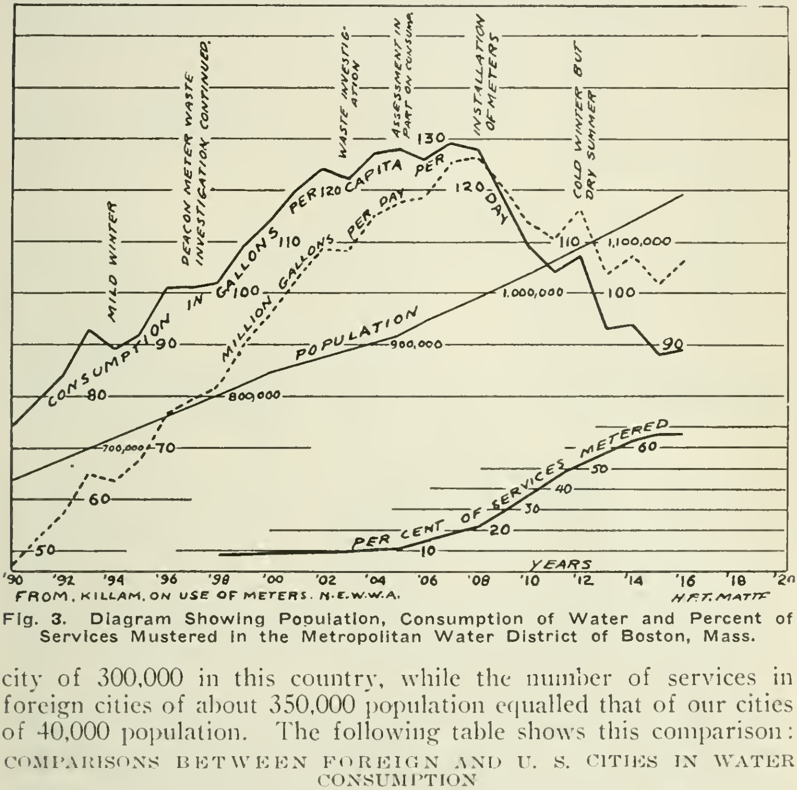


Fig. 3. Diagram Showing Population, Consumption of Water and Percent of Services Mustered in the Metropolitan Water District of Boston, Mass.

city of 300,000 in this country, while the number of services in foreign cities of about 350,000 population equalled that of our cities of 40,000 population. The following table shows this comparison:

COMPARISONS BETWEEN FOREIGN AND U. S. CITIES IN WATER CONSUMPTION

City	Population.	Number of taps.	Per capita G. P. D.	No. of taps per thou. pop.
Berlin	2,183,500	29,707	22	13.5
Chicago	2,572,000	305,717	245	119.0
Paris	2,714,000	93,035	30	34.4
Vienna	2,000,000	33,900	14	16.9
Hamburg	864,800	24,300	39	29.1
St. Louis	740,000	116,014	130	157.0
Amsterdam	565,632	43,469	23	76.8
Buffalo	450,000	81,062	309	180.0
Milwaukee	430,000	59,603	111	138.6
Havana, Cuba	400,000	25,250	138	63.2
Stockholm	338,500	8,041	26	23.7
Rockford, Ill.	53,000	9,305	54	175.5
Grand Rapids	90,000	21,121	176	235.0
Boulogne, Fr.	50,000	1,698	29	34.0
Oak Park, Ill.	37,000	8,000	65	216.0
Fargo, N. D.	16,000	2,400	137	150.0
Harvey, Ill.	7,200	1,115	56	115.0

EFFECTIVE SIZE OF SERVICES AND MAINS

The data on this subject is limited, but the difficulty experienced through loss of pressure by friction from the reduced area of corroded lime-coated service pipes and water pipes filled with algæ, crenothrix and tubercles, indicate the importance of the effective size of service pipes and mains on leakage and waste. Water bills on metered premises in which leakage and waste exist often double in size after the renewal of service pipes, both in the ground and in the interior of the house, especially when iron pipe has been replaced.

The following table compiled from some experiments conducted by the New York department of water supply, gas and electricity, throws more light upon the subject:

Pressure in street mains required to give the tabulated discharge through a corporation cock and 30 feet of lead service pipe.

Gals. per Min.	In. service	¾-in. service	⅝-in. service
5	....	2 lbs. sq. in.	3 lbs. sq. in.
10	....	5 lbs. sq. in.	10 lbs. sq. in.
15	3 lbs. sq. in.	11 lbs. sq. in.	23 lbs. sq. in.
20	5 lbs. sq. in.	18 lbs. sq. in.	38 lbs. sq. in.
25	8 lbs. sq. in.	28 lbs. sq. in.	54 lbs. sq. in.

This table also gives the difference between the pressure at the main and the house side of the service under pressure.

USE OF WATER METERS

Having considered the items which affect domestic water consumption as governed by local conditions irrespective of industrial and other usually recognized conditions, we may now discuss the meter question.

Can one imagine a gas company or an electric utility selling its commodity without measuring it? Doubtless though it is easier to tolerate the waste of water because it is not seen or appreciated. Gas leakage is offensive and dangerous. Wasted electricity is manifested by motion, light or heat; but water disappears unnoticed into the sewers. Yet the speaker knows that in an Eastern city where electric-light current was sold under the flat rate system, electric-light bulbs on numerous porches remained turned on all day long. Queries brought the answer that it did not matter as there was no meter. What can the effect be on the water consumer of this type when the water consumption is not metered? In fact, in this same city, which was only 28 per cent metered, the fixture leakage per capita as determined by an extended survey was 205 gallons of water per day.

Any student of water consumption and waste knows that underground leaks contribute little to the waste included in high per capita statistics. From his experience in Oak Park and elsewhere the writer affirms that the periodical inspection of fixtures in lieu of complete metering is entirely unsatisfactory. When unavoidable

leakage will occur through meters, what can be expected when there is no automatic check up on the consumption? In Oak Park it has been observed during the past four years that the annual number of high bills complained of, including those places at which the same conditions obtained two or three times a year, dropped from 33 to 10 per cent of the total number of services, due to the education of the consumer. Without meters there would have been few complaints and much increase in waste and leakage.

It is most difficult to control fixture leakage by inspection on account of the recurring of the waste as soon as the inspection

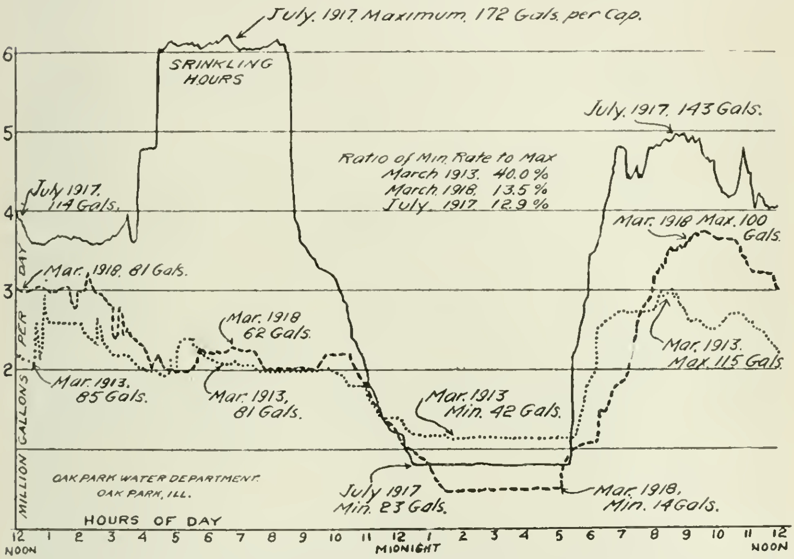


Fig. 4. Curves Showing Effect of Reduction of Water Waste Upon Maximum and Minimum Rates of Consumption, Oak Park, Ill.

has been made. In order to do the work that the meter does, it would be necessary to make inspections every month, at least, and in the case of an ordinary residence, it takes about four times as long to make an efficient inspection as it does to read a meter. In apartment buildings an inspection is a thankless job because all the occupants are seldom at home at the same time. The work, therefore, is usually slighted.

It has been found also that efficient fixture inspection is more objectionable to tenants than meter reading because the inspector has to pry into the privacy of the home. The landlords who dislike to pay plumbers' bills for the repair of poor plumbing are the ones who object to meters. In New York it was noted that after six months' work the inspector was stopping leaks at about the same rate as the leakage previously stopped was reappearing.

Unmetered water in completely sewered cities with universal

sanitary facilities is usually sold at less than cost per thousand gallons.

In Boston, with the gradual introduction of meters up to 60 per cent, the per capita consumption dropped from 130 gallons to 90 gallons, and in this city vigorous house-to-house inspection was previously practiced. The same may be said of most cities which are metered, although in a few owing to lowered water rates, with too great a minimum allowance, industrial use, and other factors which are mentioned above, the curve is more erratic.

EFFECT OF METERAGE IN OAK PARK AND METHODS OF CONTROLLING WATER WASTE

For the past five years the water department of Oak Park has made an intensive study of water consumption with a view of reducing the waste to a minimum, and consequently reducing the quantity of water purchased from Chicago. The city is and always has been 100 per cent metered, and it has been found that without meters a further material reduction in needless waste would have been an impossibility. In 1913, according to the accepted standards, the Oak Park per capita consumption of 75 gallons was very low indeed. The night rate of consumption for the total system, however, was 58 per cent of the average daily consumption, while 20 per cent seemed to be a fair ration for a city composed principally of high-class residences with few industries.

As a result of the waste campaign the daily per capita consumption of Oak Park has decreased from 75 gallons in 1913 to 65 gallons in 1918. Yet who can say that Oak Park is not one of the most sanitary cities in the State of Illinois—if not in the whole country?

There are no privies in this city, every house being connected with the sewers. All the consumers have the benefit of water-closets, 95 per cent have bathtubs; and the bathroom consumes about three-fifths of the water used for domestic purposes. Moreover, every building has a lawn, every street has a grassed parkway on each side of the roadway. From inspection of records of sanitary surveys in various cities with lower and even greater per capita consumption than Oak Park, it was found that the number of premises not connected with the sewers varied between 20 per cent and 80 per cent of the total. Every home in Oak Park is connected with the water supply and there are no active wells except two deep wells used by a gas company as a supplement to the city water, and consuming one gallon per capita. In other cities of which we have record, the wells number 5 per cent to 81 per cent of the total number of buildings.

From the foregoing it follows that Oak Park people should use more water than the average city regardless of relatively small industrial use, because in many cities with industrial plants the big users have access to river, lake or well supply and use the city water only for emergency use or for drinking water.

THE WASTE PROBLEM

It will be noted that the night rate of pumpage will often be from 80 to 90 per cent of the average daily consumption. This is indicative of much waste. Too much consumption is generally assumed for industrial and other night uses. Such should be determined, not estimated. In Oak Park the night rate, which is considered the waste barometer, was reduced from 56 per cent to 21 per cent of the average daily consumption in the four years between 1914 and 1918, inclusive.

The waste problem was attacked along various lines, some of which are not commonly associated with water consumption. The elements substantially affecting waste elimination as developed in the four years between 1914 and 1918, being these:

One hundred per cent meterage; efficient maintenance of meters; efficient complaint bureau, including education of consumers in cause and remedy of needless waste; strict collection of high bills due to leakage or waste; periodical waste surveys; comprehensive and workable water ordinance, or rules and regulations, with their strict observance; centralized control of the water department.

Meterage—With regard to the first item, 100 per cent meterage, this means that all water pumped or otherwise delivered into the system is measured at the distributing point no matter where located. Included among the services metered are all municipal buildings, watering troughs, drinking fountains, street sprinkling, water used in parks, water used in the construction of houses and all dwellings regardless of size or character; together with fire hydrants when used for other than fire purposes. It is admitted that in the construction of buildings and in the case of fire hydrants that sometimes more water is wasted than is measured, but it was found that the moral effect of the meter had a great weight in minimizing the unlawful use of water. It is, in fact, a visible permit. Selective metering has been proposed and widely adopted in many large cities in order to reduce expense, but under that basis it would be necessary to meter only 10 per cent of the Oak Park services, for Oak Park would be considered one of the good controllable districts adapted to periodical inspection, in a city like Chicago, for instance. Under this method, too, the wastage must have taken place before the necessity for stopping it will have become apparent.

Maintenance of Meters—The second item, the efficient maintenance of meters, is more important than appears at first glance. Meters should be repaired as soon as possible after being reported stopped or otherwise defective. This condition of the meter is usually detected by the readings supplemented by observations of the meter reader. All suspicious variations in the readings, both high and low, should be investigated promptly. It has been found that frequent readings taken not less than four times a year, preferably more, give satisfaction to the consumer in measuring accurately all the water that is used and in giving ample warning of unavoidable excess consumption. The periodical testing of meters,

such as once every five years, has disclosed many unsuspected defects caused by undue wearing of parts, or the detection of tampering by the consumer. In Oak Park the test of meters which were used by the private company preceding municipal management disclosed under-registration varying between 10 per cent and 50 per cent, with an average of 2 per cent for the entire system. It was also found that in several cases where the bills were not high in spite of very small leakage that the meters did not register leakage as small as 30 gallons per day.

Complaint Bureau—The efficient complaint bureau and the education of the water consumers are important both for the satisfaction of the water-taker who tends to regard the meter with suspicion and for the peace of mind of the water department executive who realizes that it does not pay to antagonize citizens. The systematic handling of complaints is infinitely more satisfactory than adverse arbitrary decisions, or spineless methods of leniency caused by fear of political pressure or favoritism. Every high bill can and ought to be explained. The problem is really one of education. In Oak Park the campaign was begun by utilizing the backs of the water bills for admonitions to the consumer referring to the waste of water. This was supplemented by letters to each complainant with follow-ups in order to test the reduction in consumption after the repair of leaks. The meter readers report all suspicious sounds of running water, although not attempting to trace the cause in order to save time, and the rest is handled in the office by the complaint clerks. If the consumption is abnormal, a special call is made by a complaint inspector before the waste is brought to the attention of the consumer. It was noted that if notices were sent to the consumer before the investigation, he often repaired the fault and then insisted there must be a mistake or that the meter was incorrect, because there could be no leaks. Hence the adoption of a policy of locating serious trouble before reporting it.

No one in Oak Park has ever been obliged to stint in the use of water in order to receive reasonable bills. In fact the leaks consumed 3 to 10 times more water than the consumers themselves can actually use for all purposes. Newly arrived residents from Chicago and other cities with the flat-rate system, have an inborn dread of meters, and when these persons have exorbitant bills, they often begin to be miserly in the use of water, even attesting to the fact that the strictest economy was practiced. Sometimes they threaten to return to their former homes where they had a square deal. Our investigators proved that, in every case of that kind, there were toilets leaking at the rate of 1/8 to 1/2 gallon per minute. Sometimes the waste was so small that the watching of the meter did not readily indicate the quantity. Sound is really the best indicator of leaks. This is explained to the consumer who thereafter manages to use all the water he needs, although keeping down the bills. Often a warm meter advocate is thus obtained. It is always a good policy to give the consumer the benefit of the doubt

and let it be known that the department is glad to correct errors. In many cases diplomatic cross examinations will uncover sources of waste which the consumers do not realize. It is dangerous to try to prove that the complainant is wrong until you can show him where. Rectify errors promptly. *Service* is the important element in popularizing the use of meters.

Aside from the waste through fixtures, high bills are caused by leaks in toilets, broken underground pipes in basements, defective toilet valves or ball-cocks, dripping faucets, thermostats, water motors, pumps operated by water power, defective stop-and-waste cocks, leaking valves, breaks in pipes under cement floors, and between walls, water used for cooling food, water wasted to obtain a cool drink, or to procure hot water from defective heaters,

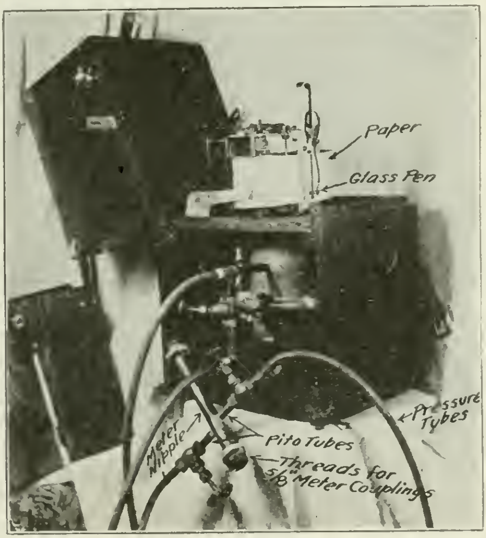


Fig. 5. Recorder and Meter Used for Determination of Rates and Character of Domestic Water Consumption.

children leaving faucets open, lawn sprinkling with hose without nozzles, the flushings of waterclosets uselessly after use for purposes for which they are not designed, such as garbage receptacles, leakage through tanks in attics and by allowing water to run continuously in order to prevent freezing, or into washtubs or lavatories for washing purposes, instead of filling the bowls or tubs before using.

Domestic Waste Detector—For causes where the department was unable to determine the cause of high bills owing to the fact that there was no leakage and that the consumer was sure he was not wasting water, a recording detector was designed, which when

substituted for the meter gives a graphic record of the consumption for 24 hours or a week. This device consists of a piece of brass pipe one-half inch or three-fourths inch in diameter and 7 inches long, into which are inserted two brass tubes one-sixteenth inch in diameter, one pointed upstream and the other perpendicular to the axis of the pipe. For convenience, these orifices or pitot tubes are soldered into one-eighth inch brass nipples. Two needle valves and strong rubber tubing complete the meter. A special type of recorder with a rapidly revolving chart so that drafts lasting only one-half minute could be detected, was constructed which indicated at what time and how long faucets were left open for baths, for washing dishes or clothes, or for lawn sprinkling; how often toilets were flushed, together with a record of all leakage of one and one-

Fig. 6. Domestic Waste Detector on Duty in 15" Tile Meter Box

half gallons a minute or more. In fact, it was found easy to determine at what time the consumers rose and retired and whether they got up during the night or not.

As shown in the illustration, the short piece of pipe (in reality a brass meter nipple into which are soldered permanently two pitot tubes) is inserted into the house service either in place of the meter or connected in tandem with it. In all, only two tubes were necessary for the range of consumption which exists between a four-room bungalow and 24-apartment building. In the first experiments the pitot tubes were connected to a mercury U-tube, by means of which rates ranging from less than one-half gallon per minute to 30 gallons per minute were measured by using the one-half inch and three-fourths inch nipples. A camera provided with a revolving sheet of bromide paper, 3 inches wide, was designed and adjusted so that the lens magnified the deflections through a slot about eight-thousandths of an inch wide. A pocket

flashlight supplied the illumination, through a condenser and the power was furnished by a single-cell storage battery constructed for the purpose. The only drawback to the device was that the high deflections were beyond the range of the slot, although small leakage was detected which the disk meter failed to record.

The next step after fruitless attempts to alter the quantitative measuring device of the displacement meter so that it would register in gallons per minute, was to design a recorder which could take care of all flows. This new recorder, which is shown in Figure 6, will detect rates as low as one and one-half gallons per minute,

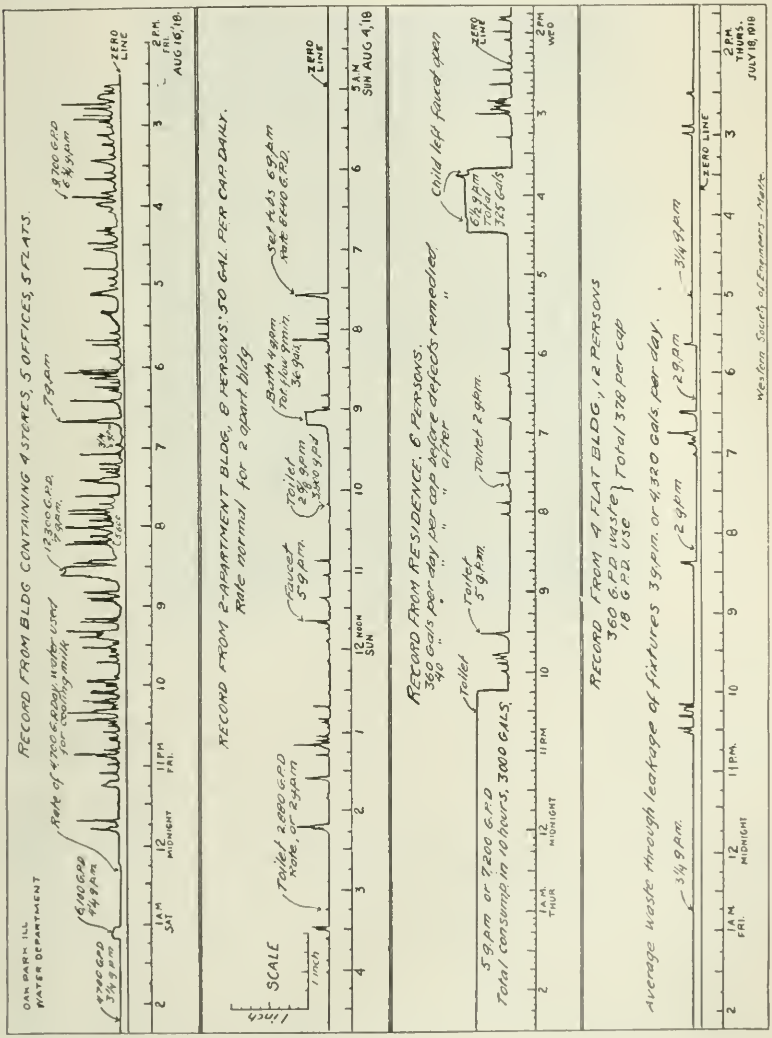


Fig. 7. Records from New Domestic Water Waste Detector, Oak Park, Ill.

and there is no limit to the maximum recording capacity if larger meter tubes with lower center velocities are used. The diaphragm is constructed of one-eighth inch mechanical rubber, and it is surprising to note the power transmitted through the stuffing box. The recovery after a short draft is rapid, even at maximum velocities, as indicated by the accompanying copies of actual records. The recorder is not extremely accurate but frequent rating by means of the regular meter-testing outfit indicates that it is amply dependable. It has been used successfully in connection with a 2-inch Venturi meter, in making waste surveys by means of the hydrant

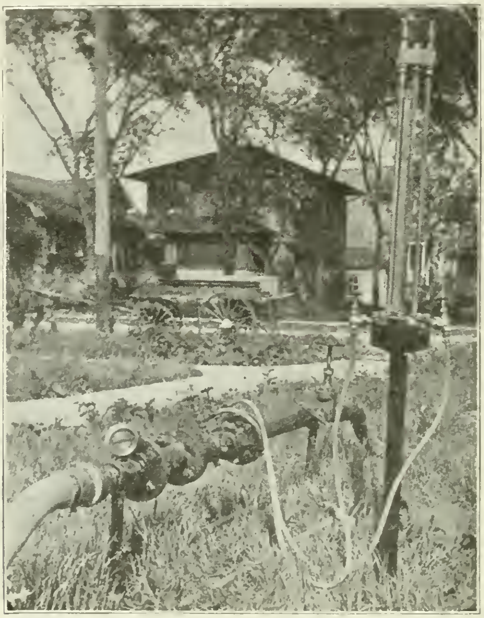


Fig. 8. Hydrant and Hose Method of Making Water Waste Surveys Using 2 in. x ⅝ in. Venturi Meter with Murcury Barometer Monometer.

and hose method, and gives much assistance in determining the varying consumption in the district tested, so that the leakage can be ascertained.

Plumbers invariably mislead the consumer by failing to appreciate small leaks and by discrediting the meter. But Oak Park water-takers are rapidly becoming educated in spite of this. After being shown repeatedly the waste which plumbers failed to locate, and seeing the effect of the stoppage of leaks which, according to the plumbers, could not amount to more than 10 gallons a month—they refuse to be sidetracked.

Payment of High Bills Caused by Leakage—Regarding rebates on high bills which were caused by leakage, we find that to reduce

these indiscriminately is to defeat the purpose of the meters. As stated before, reliance should be placed upon educating the consumer rather than in the practice of allowing reductions in order to avoid adverse criticism or to satisfy some influential citizen. Water-takers easily fall into the habit of depending upon leniency if such is known to be a possible way out of their difficulties. The average consumer can bring the plea of first offense and a promise to be careful in the future. The way it works out though is this: If a rebate is allowed in one case, the tendency of the authorities will be known throughout the community in a short time, and it will be very difficult to enforce payment of other similar bills. If a complainant feels that the water department is lax, he will not exert himself to keep his fixtures in repair. If, on the other hand, the water officials are known to be severe and exacting, and absolutely impartial, the majority of the consumers will be satisfied that there is an advantage in being on the alert. The minority, it is true, will complain and accuse the manager or other executive of unfairness, but the fact that everyone has been treated alike and that there are no favorites will permit a very successful operation of the "no reduction on account of leakage" policy. Oak Park speaks from experience. Better to allow a lower rate on the water, approaching the cost per thousand gallons in the case of unavoidable leakage; or else adopt a partial-payment plan or both. But *charge for every gallon wasted*. The lesson will strike home and be appreciated throughout the community.

Waste Surveys—Waste surveys are very difficult to make and most unsatisfactory in unmetered cities. The speaker has made a number of district waste surveys in many parts of the United States and was always disappointed at finding that the high consumption was due to fixture leakage distributed throughout the system. Periodical waste surveys, however, in a metered city are necessary to locate the underground leakage and reduce the non-revenue-producing consumption to a minimum.

In making waste surveys the most convenient method is to make, first, a rough survey of the entire city by means of a pitometer. This is done by isolating certain districts by closing gate valves and measuring the supply through one of the mains left open to serve as a feeder. It is possible on small systems to make the preliminary test by shutting down those districts entirely for a few minutes, especially in the residential sections and note the drop in the rate of consumption as indicated by the recording chart at the pumping station or reservoir, or wherever the master meter may be located, providing it is on the distributing system.

It is often found, however, in districts which are completely metered that the velocity of the smallest feed main is so low that it is impossible to obtain an accurate record of the consumption if there are no large leaks. It is then necessary to by-pass the flow of water through a small pipe, 2 inches or smaller in diameter in order to increase the velocity. This is commonly called the hydrant-

and-hose method because the most practical way of doing it is to feed from a fire hydrant, without the district, through a fire hose to a hydrant within the district. Oftentimes a regular displacement meter is used and the rate is obtained by noting the readings of the meter at regular intervals. This method is not a very useful one owing to the fact that several drafts may occur during the test. In Oak Park two other methods have been used, one consisting of a 2-inch Venturi meter with a five-eighths inch throat which can accurately record rates from 3 gallons to 50 gallons a minute. The other is by means of pitometers inserted into short pieces of pipe 2 inches or smaller. Thus a quantity as low as one-fourth of a gallon per minute can be measured.

Contrary to the usual method of making waste surveys, all tests are made during the daytime, after determining the best hours in which the flow is somewhat steady, from inspection of the Venturi meter at the pumping station. The districts tested varied between one-fourth of a mile and two miles in length. By being able to watch the rate of consumption, it is rarely found necessary to be on the job for more than half an hour at a time in order to determine the minimum rate of consumption.

The exact population of the district tested is obtained; as well as the average daily consumption through the domestic meters—the former from the prevailing school census and the latter from the water accounts. Thus an estimate of the legitimate rate exclusive of the underground leakage is determined. In all cases where there is not much leakage the normal pressure is maintained through 600 feet of fire hose. In order to bring the reading within the limits of the monometer where the flow is abnormal the valve on the meter is throttled. In one case a rate of 60,000 gallons per day at 10 pounds pressure in a stretch of pipe only one-half mile long was observed, the normal pressure in the mains being 45 pounds per square inch. Subsequent investigation by means of the aquaphone disclosed six service leaks which wasted water into the sewer at the rate of 200,000 gallons a day. This meant a leakage per capita rate of 305 gallons per day, while the service meters indicated only a total per capita consumption of 45 gallons, but after the repairs were made the leakage rate per capita dropped to 10 gallons a day.

Water Ordinance—In order to be able to operate the water department efficiently it is necessary that a comprehensive and workable water ordinance be adopted and followed to the letter. All the employes and officials should be able to follow a definite, unswerving policy with a minimum number of loopholes to be detected by skillful lawyers. The water ordinance is either legal or it is not. If there be a number of rules which have become a dead letter or are so ambiguous that the executive does not attempt to enforce them because be feels that they would not hold in case of a lawsuit, they had better be tried out immediately or else repealed. The efficiency of a water department is greatly impaired

if there is a conflict with other city laws, as in the case of many municipal plants.

In Oak Park the water ordinance was revised and made to suit local conditions by the management and made to cover the operation of the water department in all its phases, to conform with modern requirements. The ordinance was passed by the village trustees and has been in force for three years. It has been followed to the letter, every consumer being subject to the provisions without exception. Thus it has been possible to maintain the efficiency of the working force by means of an available definite policy and to avoid discrimination caused by unenforceable rules.

No.	Class of Buildings	Size of Pipe	Gals. per Day per Mile of Pipe: Minimum Rate or Leakage	Gals. per Day per Mile of Pipe: Av. Daily Cons. From Meters	Gals per Day per Cap.: Min Rate	Gals per Day per Cap.: Av. Daily Cons From Meters	Number of Persons per Mile of Pipe	
1	Medium Class Bungalows	4"	4,000	15,300	7	26	602	
2	" " "	6"	1,090	9,700	17	27	358	
3	" " "	6"	2,170	9,500	6	27	355	
4	" " "	6"	4,000	20,200	5	27	744	
5	" " "	8"	4,040	17,400	10	43	413	
6	Cottages and 2 Apt Buildings	4"	7,920	9,800	29	36	275	
7	Medium Class Bungalows	6"	620	2,500	5	20	124	
8L	First Class 2½ Story Cottages	6"	300,000	37,000	357	44	840	8L
8	" " " " "	6"	14,000	37,000	17	44	840	
9	Stores, Garages, Large Apts	10"	15,330	30,700	36	73	422	
10L	First Class Residences	4"	237,400	39,600	393	65	604	10L
10	" " "	4"	16,960	39,600	28	65	604	
11	Medium Class Cottages	4"	3,150	21,700	4	29	753	
12	2 Apt Houses and Med. Cl Cot	6"	11,050	26,400	17	40	667	
13	" " " " " "	4"	31,050	34,400	44	49	700	
14	" " " " " "	4"	35,960	32,000	39	35	922	
15	" " " " " "	4"	13,770	36,700	17	45	819	
16	Medium Class Cottages	4"	1,260	28,800	2	46	632	
17	First Class Residences and Apts	8"	11,740	42,900	16	60	721	
18	" " " " "	4"	1,700	45,800	2	59	777	
19	1st Class Res and Med Cl. Apts	4"	13,700	38,500	22	62	624	
20	High Class Residences	6"	1,740	33,000	4	75	438	
21	1st Cl. Res. and Med Cl Apts	4"	1,180	37,700	2	55	687	
22	" " " " " " "	6"	18,170	24,800	39	53	466	
23	Med Cl Cottages and Apts	6"	16,950	20,600	46	56	365	
24	First Class Apts and Cottages	4"	36,980	31,500	46	39	810	
25L	Medium Class Bungalows	6"	42,850	10,460	132	32	323	25L
25	" " "	6"	590	10,460	12	32	323	
a	Averages, Before Repairs	4"-10"	28,600	26,480	50.5	46.6	568	
b	" After "	" "	12,700	26,480	22.4	46.6	568	
c	Average Entire Water System	4"-16"	8,700	27,200	20.3	65.0	420	
d	Average Total Domestic plus Losses in Entire System	" "	Entire System 5,800	21,600	13.7	52.0	420	

Fig. 9. Data from Hydrant and Hose Waste Survey

This table is representative of conditions of the water system of Oak Park, Ill. In the district tested, containing a population of 7,436, there were 1,690 services and 13 miles of mains.

Centralized Management—It follows from the foregoing paragraphs that all the divisions connected with the operation of large water departments must be under centralized management. It would be better if many municipal plants were made an independent branch of the municipal government. There would then be fewer failures in the operation of municipally owner utilities; failures which are concealed by taxes. There is little incentive for efficiency in operation, if the superintendent or manager makes a decision, and is obliged to back down because the complainant is able to obtain a concession from some other city official higher up, who is not vitally interested in the operation of the department. It is discouraging if the manager has outlined policies which resulted

in a saving to the department and finds that the gains made are taken advantage of by some other municipal division which is not operated efficiently; or used because other funds have been exhausted. It is impossible to prevent needless waste of water if certain organizations or institutions are allowed free water against the advice of the manager, or if the manager is continually compelled to yield to pressure from some political adherent of the members of the city council.

In the case of complaints on account of high bills, it is disconcerting to attempt adjustments and give satisfaction if the money is collected in one department, "shut-offs" for non-payment of bills handled in another and the meters read and accounts rendered in either of the foregoing or yet in a third one, all these different divisions being independent and under different executives. Unless all policies originate in the same department, there will be neither co-operation nor co-ordination.

DISCUSSION

C. C. Sanir: One of the first points brought up in this paper was about the pressure being maintained throughout the day. In Chicago we have attempted to remedy that by making a regular pressure charge for each pumping station, and we have succeeded in taking care of that part very well. The size of the services is another matter that is being regulated in Chicago by making up a table of standards. In the city about 55 percent of the revenue in the water is obtained from the meter users, while only twenty percent of the water, I think, is metered.

Some of the arguments we have to contend with in talking for meters and one of the worst arguments is that water is free. We have Lake Michigan at our doors and water ought to be as free as air. We could say that electrical power should be as free as air because where does the electrical power come from? It is a matter not generally understood, in that it is a matter of transportation. The water department is in the business only of transporting the water from the lake to the faucet, where it is handed to the consumer. If the people understand that we are in the transportation business they will have a different view of the question.

About the matter of opposition to meters in Chicago. We have watched this for several years and we find that it is the people —they do not understand. They oppose the water meter; the small home opposes it; the landlord opposes it; the saloon owner opposes it—he opposes it because he is a big user of water and a waster of water.

There are twenty-six hundred miles of water pipes, ten major pumping stations. Do the people know how much coal it takes to run a pumping engine a day? Do they know that if they would stop wasting water they would save a hundred thousand tons of coal a year? Do they know it would keep fifty thousand people warm or heat ten thousand homes? All those things could be put before

the people and I think they would think a little harder about the wastage.

A fallacy peculiar to the people of Chicago is that they think the stock yards are using most of the water. The water pipe extension has made a survey of the stock yards and the consumption was thirteen and a half million gallons a day. The water consumption of the entire city was over 500,000,000 gallons a day. Ninety-two percent of the water going into the stock yards was accounted for in the meter, so they cannot say that the stock yards is abusing or wasting water. They use all they need and they pay for what they get. Nobody can complain of conditions of that kind.

I made a comparison about three years ago of the Oak Park consumption. We took the Venturi meter readings there and on the same day we made protometer readings in Evanston. The two towns are similar. They are almost the same size, the same class of people live in them, the homes are practically the same—high-grade residence neighborhoods. The city of Evanston was only partly metered at that time and was using filtered water. The town of Oak Park was buying its water from the city of Chicago, unfiltered water. The maximum consumption in Oak Park, or the peak load in Oak Park, did not come up to the lowest consumption at any time of the day in Evanston, and, as I remember, the peak load of Evanston was over three times what it was in Oak Park. I think nobody will dare go out and say that Evanston has better homes, better gardens or better lawns than Oak Park. I do know, though, that there were people in Evanston who would put their hose out in May, turn the water on, and the next time it was turned off would be in October, when it was frost-bitten.

F. G. Vent, M. W. S. E.: I believe the average tax-payer is a good deal in the same position as myself. He pays ten dollars a year for water and is not satisfied with it. The waste that goes down the pipes has a good effect in helping clean out the sewers. If the waste were absolutely eliminated we would not have so much water run through the sewers. In the case of sickness a little extra water is a mighty good thing to run through the sewers. Scarlet fever is often carried that way. The question is one that vitally affects every person as a citizen and I would like to see a question like this eventually brought to the tax-payers in the form of a referendum vote. I believe that is the proper way to settle it; get an expression of opinion from every individual using it.

William Luscomb: In regard to the argument that it is necessary to waste water to bring about a sanitary condition, I might say that Gary, a city of 47,000, is 100 percent metered. However, there is about 97 percent of the water that is furnished by meter. In the balance of the cases, the meters are connected to the pipes just as a matter of information, to determine the extent of the use or waste in places where the water was furnished at flat rates. We are not bothered with epidemics of scarlet fever, nor any other disease due to the city being 100 percent metered. I believe that statistics

would prove that, in cases like Oak Park, Gary or other places that are 100 percent metered, it has no detrimental effect on the health of the community.

It seems to me that unless allowances are made for the water furnished for industrial, commercial uses, and similar purposes, it is rather erroneous to base the extent of use or waste. In our case, until the war ended, we were furnishing the Etna Explosive Company more than two and a half million gallons of water every day. Their patronage meant just one additional customer on our records, but since the war came to an end their water consumption has been cut down to practically 100,000 gallons per day, and it has made a great difference in regard to the per capita consumption, based on the pumpage.

Mr. Vent: There was an epidemic of small pox in Gary last year which might have been on that account.

E. S. Nethercut, M. W. S. E.: I live in Evanston and have been interested in the effect of meterage on the water situation there. I think we were using, before the meters were introduced, approximately 230 gallons per capita, and I was very much surprised to think that any person could live comfortably on a less amount, but I kept a very careful record of the meter in our house for the first ten months and I find that the consumption has been reduced to 72 gallons per capita. There has been no inconvenience at all in connection with it. The difficulty in Evanston is covered by a point made by Mr. Matte in his paper, namely, that the water works operation is not a separate and distinct part of the city administration. At least fifty percent of the money received for the use of water in Evanston has been used, not to maintain a water system, but to run the city government. Water rates in Evanston are abnormally high—about twice as high as in Oak Park. The explanation of this may be that the Evanston water is filtered, but even that could not explain the large difference in the price of water. In addition to reducing the amount of water used to 72 gallons per capita per day, the water bills have been reduced, and are now two-thirds of what they were on the flat rate system.

Harris S. Keeler: There are just one or two things I wish to say to emphasize the importance of this question in Chicago. First, it means better service. The reason the people are not getting service on the upper floors is on account of the waste. The sanitary conditions would be better if the people could get water. In the matter of dollars and cents, if a ten year meter campaign could be started; in other words, if ten percent of the services could be metered each year until the job was completed, there are enough plants now in Chicago to take care of the city. The only thing would be the matter of replacements. In dollars and cents that would mean to the water users of Chicago, interest, operation and maintenance. Depreciation would mean a net saving after the meters were paid for by the city, installed by the city, operated by the city, of $135,000,000. That is a huge sum, it looks pretty

big, but it is easily there. There are at least 100,000 tons of coal that are being wasted every year pumping this water that so many people think is free, besides all the other charges that go with the consumption of coal.

DISCUSSION BY LETTER

John Ericson, M. W. S. E.: There are certain matters about which one cannot say too much nor repeat too often, until the object sought has been gained. I consider the subject under discussion one of those. I shall, therefore, take the liberty on this occasion to repeat my doings at other times, both here and in other places, namely, the advocacy of a general introduction of water meters in Chicago, and present a short statement as to how, why, and when the serious agitation for such a step was inaugurated.

During the early nineties the water supply situation in this city was becoming very serious in certain districts, there being no pumping station located west of the old station at Ashland avenue near Twenty-second street. Plans were then prepared for two stations simultaneously, with necessary supply tunnels, each station with an initial capacity of 60 million gallons per day. These stations were located, one at Springfield avenue and Bloomingdale road, and the other at Central Park avenue and Fillmore street. They were both ready for operation at about the end of the year 1900. After these stations had been placed in operation, adding 120 million gallons per day to the available supply, and with provision made for an additional 80 million gallons daily by simply adding two pumps, one to each station, it seemed that the city would be well taken care of for a number of years. The fact of the matter was that, notwithstanding these substantial additions, there soon came complaints from both these and other districts of an inadequate supply, and the two additional pumps were installed as quickly as possible.

When the first substantial additions to the system did not seem to bring the great relief that was expected, I commenced a rather extensive investigation as to the use and waste of water in the city of Chicago. This investigation pointed quite conclusively to the fact that there was an enormous leakage and waste in the water supply system. My conclusions and recommendations as regards this subject matter were embodied in one report after another to the city authorities. The recommendations made emphasized that a general metering was one of the essential necessities for a satisfactory development of the system. The only effect of this agitation was a small allowance in 1907 for the defraying of the expenses of a water survey. However, I was fortunate in securing the services of an able and experienced engineer to take charge of this work, viz., T. C. Phillips. The results of Mr. Phillips' work the very first year were such that we were able to induce the authorities to make increased appropriations year by year, until in 1911 the work was practically discontinued.

The results of these water surveys, as far as we were permitted to proceed with them, besides having brought about a con-

siderable temporary reduction of leakage and waste, were a complete corroboration of the conclusions as regards the leakage and waste of water which had been arrived at by my investigations made ten years previously.

In the meantime the bureau of engineering worked ceaselessly, planning and adding to the system in order to meet, as well as could be, the constantly increasing demands for water. This is evidenced by the increases in the system since 1900.

Without taking into account some additional pumps that are about ready for operation at the end of this year, the increases have been about as follows:

	1900	1918	Per cent of increase.
Population	1,776,236	2,600,000	46
Tunnel capacity (daily)	560,000,000 gals.	1,410,000,000 gals.	114
Pumping capacity (daily)	452,000,000 gals.	1,033,000,000 gals.	128

We have done what we could to awaken the authorities and the citizens to the situation and to the necessity of taking some advanced steps to alter this situation. We have made reports and recommendations, papers have been written for technical societies and publications. We have lectured before civic and other organizations. In some individual cases the results have been open hostility instead of the support that the proposition deserves. Some of the technical and civic organizations have shown some interest for the time being and passed some resolutions, whereupon the matter apparently has been permitted to rest.

I will, however, except one organization—the Chicago Bureau of Public Efficiency. Through Mr. Keeler, its director, this bureau has rendered and is rendering invaluable service to this community by the way in which it has taken up this subject, and through its coöperation alone I believe victory could be finally won. But in this case quick help is double help.

The forced inactivity, on account of war conditions, during the past two years, in the construction of additions to the Chicago water supply system, is making itself felt already, and, even with an immediate resumption of work on new additions, will in a very few years be a serious matter unless something worth while is done without delay to curtail the leakage and waste.

The American Beet Sugar Industry

By Martin J. Kermer,
General Manager and Chief Engineer, Cannon-Swenson Co., Chicago, Ill.

Presented January 27, 1919.

THE old saying, "Every cloud has a silver lining," has again proven to be true. Never before in the history of this country have we had such an opportunity to prove our industrial independence and the possibility of producing everything that is required for our livelihood.

Our mode of living is by no means a simple one. In fact, there is not a nation on the face of the globe that has a more extravagant standard. We certainly cannot say that we have suffered during the last four years, except, for example, that some of us had to be satisfied with two instead of four lumps of sugar in our coffee.

Among other developments, this condition has naturally attracted considerable attention to the sugar industry and also has stimulated the beet sugar industry, due to the shortage of raw cane sugar and the necessity of heavier exports from this country.

I will endeavor to give you a general description of the American beet sugar industry, with particular reference to the manufacturing process involved.

The United States is one of the heaviest consumers of sugar per capita among the nations of the world, consuming nearly one-quarter of the world's production. In 1865 we consumed 18 pounds per capita per annum, while in 1914 this had increased to 89 pounds.

This compares with the consumptions of other countries in 1914 as follows:

United Kingdom	96 pounds
France	35 pounds
Germany	38 pounds
Holland	33 pounds

In 1899 we produced in continental United States 12.3 per cent of cane and 1.6 per cent of beets, making a total of 13.9 per cent of our total consumption produced in this country.

In 1914 we produced 6.7 per cent of cane and 16.7 per cent of beets, making a total of 23.4 per cent of our total consumption produced in this country.

In 1899 this country produced 36,368 short tons; in 1914 we produced 722,054 short tons of beet sugar, or nearly twenty times as much in the latter year than in the former.

Therefore, if we consider that we are producing in both cane and beet less than 25 per cent of the total consumption, this will give you an idea of the possibility of further development in this industry.

The total acreage planted to beets in 1914 was 483,400, having an average yield of 10.9 tons per acre. The average price paid per

ton was $5 at that time. Therefore, the best crop represented a value of nearly twenty-six and one-half million dollars.

BEET SUGAR MANUFACTURING.

The beets after being harvested are delivered to the factory by wagons or cars and stored in the beet sheds.

If the beet fields are located near the factory, the farmer drives to the plant and delivers his beets direct to the beet shed. When the distance becomes too great, we have loading stations for shipment by rail.

Due to the fact that the beets are slightly lighter than water, the methods of transporting them from the beet sheds to the factory proper is rather a simple one.

Each storage bin has a flume in center through which water runs, and is connected to the main flume by a gate. The beets are raked into this flume and flowed to the factory into the beet wheel. The beet wheel is actually an elevator which lifts the beets out of the flume and discharges them into the beet washer.

The function of the beet washer is not only to cleanse the beets, but also to remove the weeds and stones and sand that come over. The weeds collect on the wooden paddles which move the beets through the washer, while heavy dirt and stones collect in the bottom of the washer.

The beets are lifted out of the washer by heavy cast iron paddles and deposited on a roller conveyor or picking table. The roller conveyor is placed on a slight incline and is made up of a train of wooden rollers 6 inches in diameter and about 3 feet 6 inches wide, set at about 6⅜-inch centers, and these rollers rotated at a speed of approximately 60 r. p. m. In case any stones or pieces of wood come over, they may be picked off, while broken beet tails drop through the opening between the rollers. This conveyor also removes the excess amount of water which comes over when the beets are discharged from the washer.

The beets drop from there into the elevator buckets and are elevated to the top of the house, where they are discharged into an automatic scale and the weight registered. Under this scale is a small storage hopper capable of holding about two tons.

SLICER

The beets drop from there into the slicer, where they are cut up in small strips called cossetes. The size of the cossetes depends entirely on the conditions and character of the beets and the results desired in the diffusion battery where the sugar is extracted.

There are two kinds of slicers in use—the horizontal type and the vertical type. Both are made up of a revolving disk, in which the knife boxes are placed. On these boxes the knives are fastened and adjusted for the proper size of cossete required. Each slicer has at least four or five extra sets of boxes on hand with the knives already set in proper position. As the setting and sharping of knives

is a very slow and careful process, this arrangement makes it possible to replace the old knives in a slicer in a few minutes.

DIFFUSION BATTERY

The cossetes are now discharged in the diffusion battery. A diffusion battery is composed of fourteen tanks or cells capable of holding each from two to four tons of cossetes, depending upon the capacity of the plant. The cells are made up with steel shells riveted to cast iron heads and bottoms. The head and bottom are conical, the head having a horizontal swinging door which is closed by a hand wheel, while the bottom, which is tapered at a 60-degree angle, has a false bottom covered with a perforated steel plate and discharge opening 24-inch diameter, closed by horizontal door hydraulically operated.

Each cell has its own vertical heater directly connected to the lower part of the bottom of the cell, while the upper part of the heater connects into the main juice line.

Under normal conditions twelve cells constitute an operating battery connected in series. Each cell has its own connection to the fresh water line; only the last cell has its water connection open through which the water enters the battery. The cossetes in this cell are the lowest in sugar constance. The fresh water enters in the top, passes through the cossetes, then rises in the heater of that cell and enters the next cell from the top, having cossetes richer in sugar, etc., etc., until finally it arrives at the 12th cell, which has just been filled with fresh cossetes. Here it enters the heater from the top, passes down through the heater and enters the cell from the bottom. This is done in order to drive off all air and prevent air pockets from forming in the cell which has just been filled. The air and gas is expelled through an air cock in the top of the cell. The rising juice in this cell drives off the air and gas formed, until finally the juice appears at the air cock. Then the current is reversed by a manipulation of the valves. The rich juice passes then just as in the other cells, from the top downward in the cell, up through the heater, from which it passes to a measuring tank, where a certain amount is drawn off. When the proper amount is drawn off, we have another cell ready with fresh cossetes, which is cut in in the same manner. The last cell through which the water entered is now cut off by closing the water valve, and the water valve on the next cell opened.

The pressure in the last cell which has been cut off is released and its contents of extracted cossetes or pulp and water discharged by opening the bottom door. The sugar contents of the pulp should not exceed .25 per cent, and should be lower than .15 per cent. Of course, these conditions depend all on circumstances. If, for example, it requires the handling of beets from some other factory, it would be advisable to rush matters by operating faster. In other words, slicing more beets than under normal conditions, and, therefore, dropping the pulp with higher sugar contents in order to finish

the campaign in the proper time. However, under no circumstances, does it pay to extract further than .15 per cent, as we are then changing non-soluble none sugars into soluble none sugars.

As I stated before, the battery is made up of fourteen cells, of which twelve are in actual operation, while of the two remaining cells one is filled with fresh cossetes and the other discharged.

A battery is operated by battery foreman and two helpers. The first opens and closes all valves and regulates the temperature in each cell. One helper attends to the filling of the cell with fresh cossetes, and his duty is to pack the cell to its full capacity, while the other helper cleans the last cell of its pulp and water and has it ready for filling.

With a hydraulic-operated battery as shown, no men are required in the pit, as the discharge is operated entirely from the floor. The old style of battery required the services of at least two men in the pit to open and close the doors which are located on the side, and also rake out the pulp and clean the cell.

It also required a good deal more wash water to clean a cell properly. It is of the greatest importance that a cell should be thoroughly cleaned of all its pulp before it is filled with fresh cossetes. If any remains in the cell we extract a certain amount of non-sugars, which are objectionable in the process.

Due to the fact that the cleaning of a cell and the opening of the doors is a nasty and wet proposition, it makes it difficult to keep men on this job and, therefore, a superintendent must be lenient and must stand sometimes for poorly-cleaned cells.

A modern designed factory therefore uses the bottom dump cell, as it not only saves labor and coal, but gives better results.

MEASURING TANKS

There are two measuring tanks for each battery. The juice flows by its own pressure to one of these tanks. The proper amount is drawn off from the battery, measured, temperature and its specific gravity taken, and from here pumped through a set of heaters to the lime-juice mixing tanks. Generally from two to three measuring tank charges are pumped to the lime-juice mixing tank. Here the proper amount of lime is added and thoroughly mixed with the raw juice.

FIRST CARBONATION

First Carbonation —This entire charge is dropped to the first carbonation. This station is made up of four or five rectangular tanks approximately 5 ft. wide, 8 ft. deep and 20 ft. high, having a bottom which is placed on an incline slanting towards the front where the discharge connection is made. Each tank is equipped with a gas distributor which is placed a few inches from the bottom.

The flow of carbon dioxide gas is regulated through a valve having a rising stem operated from the front of the tank. Each may have its own heating surface composed of copper tubes to bring the juice to the proper temperature. However, these heating surfaces

are not essential as the heating of the juice can be done very effectively by passing it through a high velocity heater after leaving the carbonation tanks. The main objection to having the heating done in the tank is that its heating surface soon becomes coated with lime and impurities and, therefore, requires frequent cleaning, resulting in loss of time; while, on the other hand, a high velocity heater may be operated for a whole season without requiring any attention.

The vapor and gases which escape from the carbonation tank can escape through a vent pipe. Due to the fact that the juice sometimes foams very badly when it is carbonated, the vent pipes are connected to a common header which in turn drains to the carbonation tanks.

Some factories instead of having lime-juice mixing tanks, mix their lime milk with the juice in the carbonation tank itself. The main objection to this method is that the lime does not get enough time to complete its re-action on the raw juice. This is especially true when they are working the mill at high speed. It has often come to my attention that the operator turns on the gas before all the lime milk has entered the carbonation tank, and in order to shorten the time required for carbonating, reduces the amount of lime which is specified. By having this done in a separate station all of these possibilities are not only eliminated, but the lime is thoroughly mixed with the juice and has plenty of time to complete its work.

The purification action of the lime on the raw juice is mechanical and chemical. The mechanical action of the lime is due to the fact that all matter in suspension, such as pieces of cossetes which are carried over with the juice, the albumen which coagulated due to the heating of the raw juice, and certain micro-organism are precipitated.

The chemical action of the lime is the neutralizing of the free acid and the acid salts and forming of insoluble organic and inorganic salts. The amount of lime required to accomplish the above mentioned results is rather small and less than .2 per cent of the weight of the beets. However, it would be very difficult to filter this liquor on account of the slimy sludge. In practice, about 2 to 3 per cent of lime is used on the weight of the beets. This additional amount of lime does not hasten the decomposition of the different substances, as only the lime in solution is active, while the excess amount of lime acts as a filter medium. When the temperature of the juice is about 175 Fahr., it requires about fifteen minutes to obtain the proper results. The solubility of lime depends upon the amount of sugar present and the temperature of the juice. The sugar binds itself to the lime, forming salts, namely, mono- and try-calcium sacharete. This, however, is decomposed to sugar and calcium carbonate as soon as the CO_2 gas is introduced. The carbon dioxide gas is forced through the liquor until it has reached an alkalinity of about 0.15 to 0.2 or 15 to 20 degrees. By one degree of alkalinity we understand the alkalinity produced by 1 gr. CaO in 100 c.c. of water.

Carbonation Receiving Tank:—After the juice has been properly carbonated the operator discharges it from the carbonation tank to the carbonation receiving tank. This is a round tank with hopper bottom, capable of holding two to three charges. The muddy liquor is pumped through a stone catcher or strainer to remove all stones larger than a quarter of an inch through a heater to the first carbonate presses.

First Carbonation Presses:—There are a number of different types of presses on the market today. The main difference between the old plate and frame press and the modern press of today is the saving of labor. While it required eight men to operate the plate and frame presses, it requires not more than four men to do the same work with a modern press.

Under normal conditions the liquor should enter the press at about 180 F. and 35-lb. pressure. The precipitate is collected on the leaves until a cake is formed. The cake is composed of lime and impurities of about one inch thickness. When this stage is reached, the liquor which is in the press and, therefore, not filtered, is discharged from the press by compressed air at about 10 lbs. pressure. Then the press is filled with hot water and the sugar is washed out of the cake. The filtered liquor that leaves the press while the cake is being formed is very clear and of a light brown color. The first wash water passing through the press is naturally rich in sugar and can be mixed with the original filtrate, while the bulk of the wash water is collected in a separate tank. The washing is continued until the wash water shows a Brix of about 1½ or a specific weight of 1.007.

Second Carbonation: — The filtered juice after leaving the presses is very clear and light brown in color, and flows by gravity to the second carbonation tank. This is a square tank having four compartments. Each compartment is equipped with a CO_2 gas distributor of the same design as used in the first carbonation. Only two of them are used under normal conditions, the other two acting as a stand-by. The juice circulates through the four compartments and the gas is forced through the juice until it has reached an alkalinity of from 5 to 6 degrees.

Second Presses:—The juice leaving the second carbonation tank is slightly cloudy, is pumped by a direct motor-driven pump through a multiple pass, high velocity heater to the second presses. These presses are the same as those used for the first filtration, but not as many are required due to the fact that we are now removing less impurities.

Re-Boiler:—The filtered liquor leaving the second presses flows by gravity to the re-boiler.

It is built on the same principle as an evaporator. The function of this apparatus is to bring the temperature of the thin juice to the boiling point in order to break up the bi-carbonates. The juice is pumped from the re-boiler by a motor-driven centrifugal pump to plate and frame presses where it is refiltered.

Third Saturation:—After leaving the third presses, it is pumped to the saturation tank where it is treated with sulphur dioxide gas. This tank is of the same design and built on the same principle as the continuous carbonation. It has four compartments, each of them equipped with a gas distributor from which sulphur dioxide is forced through the liquor.

The sulphur dioxide gas is obtained by burning sulphur in an enclosed cast iron stove into which compressed air is introduced under about 5 lbs. pressure. The gas, after leaving the stove, is cooled by passing it through a water-jacketed pipe. It is forced by its own pressure through the liquor in the saturation tank as described above.

There are other systems of continuous saturation which have proven very successful, notably the Quarez and the Lockwood.

The thin juice is now filtered once more through plate and frame presses. The amount of cake formed is very small, being about 0.1 per cent of the weight of the beets.

Evaporation System:—The clear and finished thin juice is now pumped through a heater to the pre-evaporator.

In the pre-evaporator the juice is exposed to a relatively high temperature, not to exceed 245° Fahr., for a very short time while the temperature may be automatically regulated.

The particular type of machine illustrated has the advantage of having a relatively large heating surface in a small space. The heating surface is composed of a number of large tubes having smaller tubes inserted concentrically. The steam is introduced on the inside of the larger tube and the outside of the smaller tube while the liquor circulates back and forth through a series of the smaller tubes, is discharged into a vapor chamber, where it comes in contact with the outside of the larger tubes. The vapor or steam created due to evaporation is removed and used for heating, as will be explained later. From here, the juice enters into the first effect of the quadruple effect evaporator under its own head, due to the higher pressure existing in the pre-evaporator. The juice flows progressively through the four effects of the evaporator due to lower pressure existing in each succeeding effect. In each effect a certain amount of evaporation takes place.

The heating surface of the first effect is supplied with steam of 7 to 10 lbs. gauge pressure. The vapor resulting from boiling the liquor in the first effect is supplied to the heating surface of the second effect, which in turn causes the boiling of the liquor in the second effect, and so on until finally the vapor which is created in the fourth effect is condensed in the condenser. The thin liquor which enters the first effect at approximately 14 deg. Brix or spec. gr. 1.055 is concentrated when it leaves the fourth effect to approx. 60 deg. Brix or 1.29 sp. gr.

It is withdrawn by a magma pump from the fourth effect which is under vacuum and is pumped to what are called the blow-ups or another sulphur station where the alkalinity is reduced to nearly zero.

We have now what is called thick juice which, after filtering again, is a clear amber-colored fluid and which is now stored in tanks as finished liquor ready for the crystallizing pan.

White Vacuum Pan:—The vacuum pan is primarily a single effect evaporator, making a wide range of temperature possible during concentration. The heating surface is composed of several independent copper coils arranged one above the other and supplied with live steam at not to exceed 40 lbs. gauge pressure.

The body itself is made of cast iron of cylindrical form, having a cone bottom and dome-shaped top and provided with a number of peep holes and testers.

The vapors are withdrawn from the top through a catch-all to a condenser.

The finished liquor from the storage tanks is drawn into the pan, which is under vacuum, and is here further concentrated until sugar crystals are formed. The heavy concentrated mass, known as masscuite, is discharged after the vacuum has been broken. This is accomplished by opening the large gate at the bottom of the cone, allowing the masscuits to flow by gravity into a hopper or mixer equipped with an agitator.

Centrifugals:—The white sugar contrifugals are placed directly under this mixer from which they are fed by spouts. Their function is to separate the formed crystals from the mother liquor. After practically all of the mother liquor has been removed, the remaining sugar is washed with a measured amount of pure water, resulting in a pure white sugar. This sugar is discharged to a conveyor, dried and cooled in rotary drums.

This is the finished standard granulated sugar of commerce which is now screened into various grades of fineness, automatically weighed and packed in bags or cartons ready for storing in the warehouse or direct shipment.

Second Sugar:—The mother liquor resulting from the white centrifugals is still rich in sugar, having a Brix of 78 and purity of 74. It is now first diluted to approximately 60 deg. Brix and then further concentrated in what is known as the "raw pan."

Raw Pan:—This pan has been commonly in the past of the same type and construction as the white pan, but the most modern practice is to use the calandria type, which has the advantage of slow boiling and allowing the use of exhaust steam.

The crystals in the masscuite due to the concentration in the raw pan are as completely formed as those in the white pan and is, therefore, discharged into the crystallizer where the crystals are completed, due to crystallization in motion.

Crystallizers:—The crystallizers are cylindrical steel jacketed tanks, equipped with slow moving agitators. The function of the jacket is to control the temperature of the masscuite which remains there for a number of days. From there it is discharged into the mixer and handled in the brown centrifugals, resulting in a brown sugar and molasses. The brown sugar is not a commercial article,

but is re-melted and re-crystallized in the white pan, as is also the wash resulting from the white sugar. Both may be used for topping off a strike in the white pan.

The time available will not permit the discussion of the by-products, which are, however, of great importance and of commercial value. Among these are beet pulp, a valuable cattle feed; the lime cake from the presses for fertilizer; the molasses for further extraction of sugar having potash as a by-product, or the manufacturing of alcohol.

ENGINEERING

The design of a sugar factory similar to that described above imposes limitations upon the designing engineer, which are rarely met with in any other industry. This is mainly due to the short period that the factory is in operation.

On one hand, we are limited by the fact that the plant only operates approximately a hundred days of the year and, therefore, making the investment of prime importance; while on the other hand we must have during operation absolute reliability of equipment and also must strive for high economy in the use of fuels.

HEAT BALANCE

In order to obtain high economy, the heat balance must have the most careful consideration. In a plant of this character where a great deal of heating and evaporating has to be done, it should be accomplished with the greatest economy consistent with a reasonable investment.

This points to the use of multiple effect evaporators and the Rillieux principle of drawing vapor from the different bodies of the multiple effect for heating purposes.

This method is by no means new and has been thoroughly tried out abroad, but has been rather neglected in this country due to the strong tendency here to adhere to the standard apparatus. The method of drawing vapor from the evaporator was first introduced in this country in 1898 by Mr. E. Salich of Chicago. Two factories were equipped with this method of heating, but a few years later it was changed back to the old style. Only in the last few years have they begun to appreciate and understand the great savings that can be obtained. At the present all modern factories are using it.

Having established the requirements for steam upon the most economical basis for evaporating and heating, the next step is to provide for the necessary power so that the exhaust steam available from this source can be used to the best advantage.

Power:—A certain amount of exhaust steam is required to obtain the above mentioned conditions; this result may be accomplished by the use of a reciprocating engine or a turbo-generator, either of which will give suitable economy in the use of steam. The choice depends to a considerable extent upon the means of transmission adopted.

I believe that very little doubt remains in the minds of the modern engineer that electrical transmission and drive are more convenient, reliable and economical than the use of line shafting This is particularly true in the sugar factory where trouble with belting and line shafting have been annoying and costly. This conclusion has been arrived at after years of experience and the gradual introduction of electrical equipment.

This heat balance is based on normal conditions and all quantities are expressed in percentage of the net weight of the beets sliced.

The following conditions are assumed:

Main water supply	50-60 F.
Temp. hot well	90
Temp. cossetes	40
Temp. raw juice	90 F
Temp. raw juice after heating	180
Temp. juice leaving carbonation	170
Temp. juice entering 1 presses	195
Temp. juice entering 2 carbonation	175
Temp. juice entering 2 presses	200
Temp. juice entering juice boiler	180
Temp. juice leaving juice boiler	212
Temp. juice leaving filters	180
Temp. juice entering pre-evaporator	220

Draw 125 per cent, lime 2 per cent and lime milk at 20 Be.

Cake from presses 10 per cent, with 50 per cent moisture.

The following figures are taken from the heat balance and are calculated on an average hourly basis, expressed in the net weight of the beets sliced:

Exhaust Steam from

Turbo generator, gas pump and auxiliaries

First effect evap	40%
Raw pan / Feed water heater	5%

Live Steam

White pan	13%
Pre-evaporator	13%
Sugar driers and small heaters	2.5%
Radiation losses	1.5%
Total steam consumption	75%

Assuming that our feed water is 200 F.

coal 11,000 B. T. U.
boiler efficiency 65%
steam 175-inch pressure

this condition would mean 7 lbs. of steam per lb. of coal. Therefore the coal consumption would be 10.7%.

Assuming another mill operating under the same general conditions, but where we do not use the Rillieux principle but use exhaust or live steam instead:

Exhaust Steam from		
Engines, gas pump and auxiliaries	First effect evaporation	22.5%
	Raw pan / Feed water heater	5. %
	Heaters	37.9%
Live Steam		
White pan		13. %
Pre-Evap.		13. %
Sugar driers		2.5%
Radiation losses		1.5%
Total steam consumption		96.4%

Assuming the same condition in boiler room, therefore, the coal consumption would be 13.7%. Here is a difference in coal consumption of 3.%.

Assuming a 600-ton mill operating 100 days, using coal at $4.00 per ton, this would mean a saving of $7,200.

Where the Rillieux principle is used all heaters should be located as near as possible to the evaporators in order to shorten the vapor lines, and all heaters should be equipped with condensation pumps to remove the condensation. Due to the fact that we are using vapor for heating instead of exhaust steam, we need piping of larger diameter. The above mentioned items are the only additional expense when this principle is used. As far as the evaporators are concerned, we have increased the first and second effect, but reduced the third and fourth, which also reduces the size of the condenser and vacuum pump. These items will offset each other.

DISCUSSION.

Prof. Harry McCormick: There is one point in which we are all interested—the possibility of increasing our sugar output in this country to the point where we can take care of our own needs. Mr. Kermer pointed out very well how we have done that, to some extent, in the past few years, as our sugar production in this country has increased. Most of that sugar production has come from the increase in beet sugar production, Louisiana being our only cane producing state, and there is not much cane produced there.

According to Mr. Kermer's statistics, we get 10.9 tons of beets per acre. A rather high average in sugar content of those beets is sixteen per cent. In other words, we get 1.7 tons of sugar per acre on an 83 per cent recovery from these beets, which is about the average. For cane we get from 21 tons of cane per acre in Louisiana, which, by the way, is a poor cane producer; up to 36 tons in the tropical and semi-tropical countries. The sugar content

will run from 10 to 22 per cent, giving us a sugar production of from 2.94 tons up to 7.92 tons. Realizing that the cost of labor where the cane is produced is certainly not more than it is where the beets are produced, and that the expense of producing the sugar from the cane is not greater than that from the beets, we see at once the great handicap which we have to overcome in trying to produce sugar from beets in competition with sugar from cane. Yet we have done a great deal in this country in the production of sugar from beets.

The first sugar beet factory was erected in this country about 1890. Now we have about seventy beet sugar factories in the United States.

Speaking as a chemical engineer I think we ought to emphasize the nature of the material we are handling in a sugar factory. It is a solution of sugar, rather dilute, rather impure. It contains many materials which will bring about fermentation, and many materials which will ferment when such fermentation is brought about.

Mr. Kermer remarked on how a beet sugar factory had to be almost fool-proof; that it had to operate twenty-four hours a day during the season. Any stoppage means considerable loss, because any interruption of the normal flow of juice through the house means a considerable loss of sugar. Fermentation starts in and we not only lose the sugar which is fermented, but fail to recover other sugar which is not fermented. As the percentage of impurities rises, the percentage of recovery of crystallized sugar drops materially.

All the apparatus in a sugar factory is put in for one thing—the purification of the juice, and the recovery of the sugar from the juice. We want to extract the sugar in the form of as pure a solution as we can from the beets. The juice of the beet is probably a little higher in sugar content than is the diffusion juice we get from the beets. The juice of the beets, however, as we express it, is not as pure as the juice from the diffusion battery. The chemist expresses that by saying that the beet has a vegetable cell wall which we use as a permeable membrane through which diffusion takes place, and sugar passes through that permeable membrane more readily than do the other salts which are present in the beet. We have the permeable membrane on one side and a solution of sugar, plus certain other chemical compounds on the other side of the membrane, and water outside the membrane. The sugar goes through the membrane into the water at a higher rate of speed than do the other salts, and therefore we get more sugar in ratio to the total solids in the water than we had in the beet. If we could get only sugar, then our purification process could be eliminated. All this carbonation, sulphur, limeing, etc., could be cut out entirely. The object of all these operations is to raise the purity of the sugar juice.

We start, normally, with a diffusion of from 82 to 92 per cent

purity. If we have that per cent of the total solids in the juice as sugar, the other solids, being non-sugar, are mostly inorganic salts, and our total process up to the time we start concentrating the juice is to eliminate the impurities and get the sugar solution as pure as possible.

Mr. Kermer says the juice coming from the diffusion battery contains a lot of foreign material besides the material which is in solution. It contains also material which is held in suspension. He remarks that we use excess lime there to form a filtering medium. Mechanically, lime is not a good filtering medium. It gets slimy and filters with difficulty. In some recent installations another American material has been used instead of the excess lime, in order to break up the cake by means of this material.

At different times of the beet season the condition of the cossettes which go into the diffusion differs materially. At the first of the season the cossettes are firm, plump, there is no decay set in and not much fermentation, the juice can be run through at a high rate and at a high temperature, and the sugar can be taken out much faster from fresh cossettes than it can from cossettes which have stood in storage for a long time. The bane of the beet sugar manufacturer is weather, where a freeze occurs today and a thaw tomorrow. That softens up the beets and makes them pulpy. They get bad diffusion mechanically, and get a lot of material into the juice which shouldn't be there. If, as has been suggested, we could put the beets in cold storage and keep them there until the day we wanted to take them out and run them through the slicer and then to the diffusion battery, we would have an ideal condition. We could then operate the factory three hundred and sixty days a year instead of about one hundred. But a cold storage proposition, so far as I know, has never been tried on the beets.

Some experimenters have tried drying the cossettes. In the dry condition they will keep indefinitely. The dried cossettes will also, when water is added, plump up and diffuse as well as the fresh cossettes, and in that way the sugar can be taken out at any time. I have had beets in my laboratories that were eight or ten years old, and they will diffuse just as well as the fresh beets will.

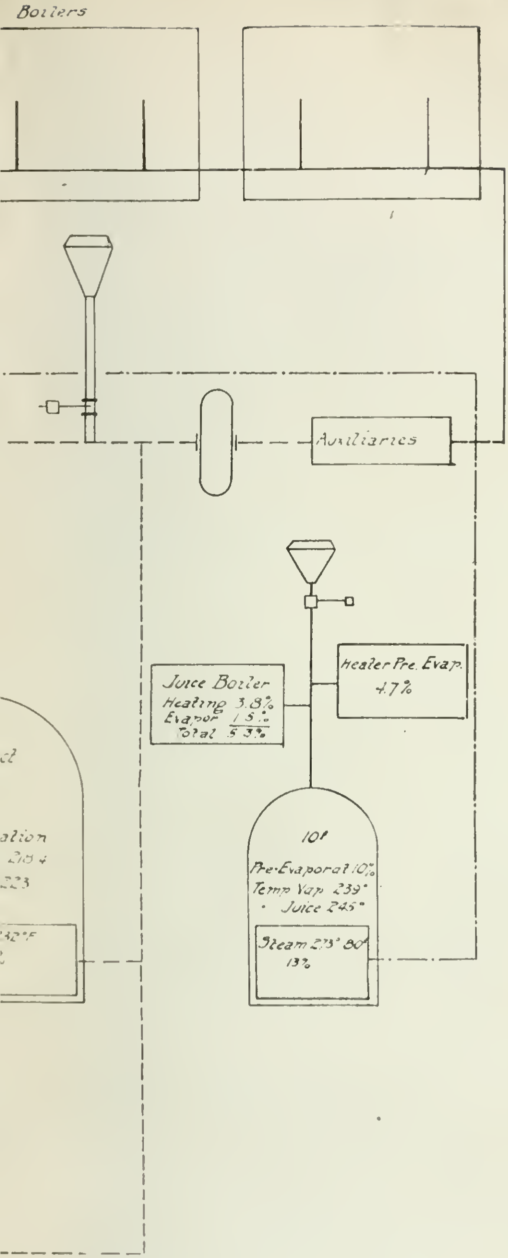
Due to the difference in the condition of the pulp, we get a difference in the rate of flow through the diffusion battery at different times of the season, and a different purity of the juice. All that means a difference in the quantity of lime which will have to be added to the juice as it comes from the diffusion battery. Those things are all controlled by the chemist, and based on his determination of the purity of the juice, and the percentage of solids in the juice, he will say how much lime has to be added and to what extent carbonation has taken place after the lime has been added. All of these operations, starting in with the first carbonation, the second carbonation, and sometimes the third carbonation, with filtering between each one, and finally the sulphuring the juice, are for the purposes of removing impurities. Starting

with an 82 per cent juice from the diffusion battery, we ought to bring it up to an 88 or 92 per cent juice by the time it goes to the first multiple effect evaporator. If we have not succeeded in materially raising the constant purity of the juice, our operations have failed. We cannot make commercial sugar unless we make it from a juice which has a fairly high purity.

Mr. Kermer mentioned briefly one type of modern filter press used in place of the old type plate and frame press. In this modern type of press the chief difference, I think, is that the leaves of the press are permanently in place; you do not have to remove the cloths; the cloths are washed in place, and after washing go back into the press for another filtration, without any change in the cloth. That not only means a material saving in labor and time in charging and discharging the press, but it means a material saving in filter cloth, which is rather important at this time, as that cloth is quite expensive.

I do not think it is more difficult to change the leaves in these presses than it is to change the cloths in the old type plate and frame press; I think the leaves can be changed just as quickly as you can change the cloths on an old type plate and frame press. I had the honor, and also the risk, of putting the first modern filter press into a cane sugar refinery. They had been running their plant from year to year on the idea that what a man did heretofore he should keep on doing to the end of time, and that nothing would filter juice except bag filters. On my advice they did put in a few modern presses and they are using them today.

The boiling of the sugar in the vacuum pan and the crystallization are points which were not brought out. Here is one of them: When sugar starts to crystallize we do not get sugar crystals all of the same size. If we allow the crystallization to go on simply by boiling down the juice, adding no new juice or fresh water, we get a combination of small and of very large crystals which would not be marketable. It is difficult to free from molasses and the trouble continues all the way from the vacuum pan. The object of the sugar boiling is to get uniform size crystals and to have the crystals of the right size. I think, personally, that one of the objections we have to beet sugar on the market is the size of the grain. You usually cannot tell beet sugar from cane sugar; it is only when you get bad beet sugar that you think it is beet sugar. Sometimes you get beet sugar crystals of a very large size, larger than you like; sometimes you get them of un-uniform size. If the sugar boiler is careful, however, you get just as nice grains from beet sugar as you do from the cane sugar. As he boils the concentrated juice in the vacuum pan and looks at the crystals on the glass he adds more juice from time to time to dissolve the little crystals, but not enough to dissolve the big ones. He gets a crystal not the size of the commercial crystal, but a size which he knows from experience will make the size of the commercial crystal when he is through with it.



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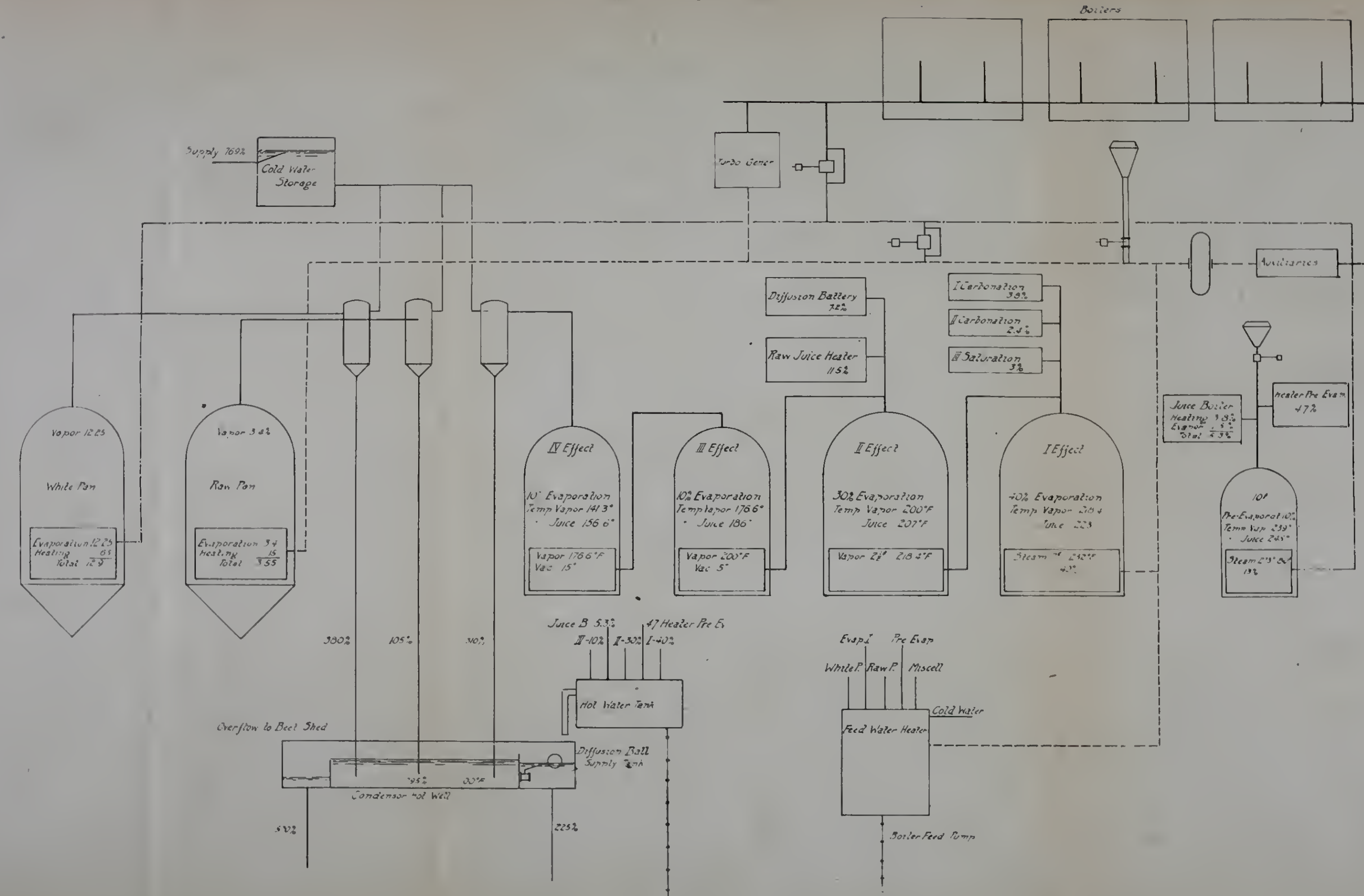
Process of Beet Sugar Manufacture



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The material is dropped into the crystallizer. It comes from the vacuum pan hot, and it makes "concrete," which is the mass of sugar crystals plus the molasses kept in motion during cooling, and during cooling the crystals grow in size. There are two objects in keeping the mass stirred during cooling: first, to get the sugar crystals the proper size, and, second, to keep the whole mass from solidifying. Sometimes an accident happens to the machinery and the crystallizers stop moving, and then the men have to go in with picks to get the material out of the crystallizers afterwards. Those sugar crystals of the proper size are intermingled with molasses. There is just enough molasses there to set it to a fine concrete if allowed to cool without motion. The object of the centrifuging is to free the crystals from the adhering molasses, and so get the crystals out cleanly, by themselves. The crystals are just as white in the molasses as it comes from the vacuum pan as they ever are; the yellow color is due to the yellow color of the molasses, and it hides the white color of the crystals. After the crystals are washed free from the molasses they are perfectly white.

My experience has been a little different from that outlined. The molasses, instead of going back to be re-boiled for sugar crystals, goes back to the limeing and carbonation tanks where the molasses is diluted up and re-purified and it goes on through the house with the diffusion juice. That, in my mind, is a little simpler than Mr. Kermer's method, as he gave it to us; there you have only one standard line of operations. The juice is coming through the house the same all the time. You have no side line where you are working up brown sugar to get white sugar. It is only at the end of the season in the houses with which I am familiar that they boil down the molasses to get brown sugar. Then it is remelted, re-limed, re-carbonated, etc., to purify it, and then boiled down again to white sugar. Those operations are repeated until at the end of the season the sugar house has only a small quantity of molasses on hand to dispose of. In the days which have just passed, molasses has been a rather valuable product, and a man has been quite careful to get all the sugar in the molasses into white sugar. Molasses has been selling readily to ferment to make alcohol, and the liquor, after the alcohol has been distilled off, has been boiled down and the potash salts recovered from it. All the beets contain potash, and the soils in which beets are grown have to contain potash. Therefore, we are coming to where we can grow beets successfully, but we will have to have some source of potash as a fertilizer for the beets. That is one secret of the success of certain European countries in making beet sugar. They have available large quantities of potash at a low prize for fertilizer.

The fundamental objection to growing sugar beets in America is the fact that the American boy, girl, woman or man will not go into the beet fields and weed and thin the beets until they are large enough to cultivate. It takes considerable hand labor to handle

the fields of beets up to the time they are large enough to plow, and as long as we insist that we will not weed beets, we will not find any very great increase in the cultivation of beets in this country for the production of beet sugar, although in this country we have conditions of soil, of climate, and water that are ideal for the growth of beets. There is no country in the world which grows beets with as high a purity of juice and as high in sugar contents as some of the American districts. We hope some manufacturer will invent and market an instrument which will thin and weed the beets.

Chairman: Mr. Kermer has referred to the electrical work connected with the beet sugar industry, and I am going to call on E. L. Clifford of the Cannon-Swenson Company, who has had considerable to do with the electrical work in connection with sugar refining. Although the introduction of electrical drive and transmission has been very gradual in connection with beet sugar factories, of late years this has had a great deal of attention, with the result that now we have a number of mills that are fully equipped with electrical drive and transmission.

E. L. Clifford: As Mr. Kermer has mentioned, while we have gained in economy by use of electrical equipment, we can hardly claim any positive gain in steam consumption from this source. However, there are certain advantages which, in part, are similar to those with which you are all pretty well acquainted with in other lines. But some of these are emphasized in sugar factories. The nature of the sugar process makes it inevitable that there will be a great deal of water vapor in the air, and even at the best, there will be occasional accidental—spill-overs—and I think it a fact that motor drive and electrical transmission can be arranged to give less trouble from these causes, and be protected better than line shaft installation.

There is a large amount of piping in a sugar mill, which makes it difficult to run a line shaft with any regularity, and usually causes a compromis where a line shaft is used, introducing undesirable features, so that in the end we have a rather complicated and dangerous system of transmission compared with the electrical installation. In the older mills it was customary to use two main engines and various other smaller engines scattered around, and the complication of piping resulted in a loss of considerable space. There were many drawbacks to this system, among others being trouble from oil getting into the steam, which can be avoided by using a turbine for generator drive. Also in connection with the handling of the juices, the centrifugal pump has been coming into use very extensively. In fact, it is used more than any other type today. These pumps are ordinarily designed for a speed that corresponds with the synchronous speed of the motors, usually twelve hundred or eighteen hundred R. P. M. motors. When we attempt to drive such pumps from line shafting of three hundred or three hundred fifty R. P. M., we have trouble with loose belts, slipping, etc. In

this particular, the direct drive is of great advantage. In a number of stations, or rather a combination of a number of stations, it is necessary to operate these stations very closely in synchronism, i. e., they have to follow an exact sequence in starting and stopping. In the old system where line shafting and belting were used, it was necessary to arrange for this by a complicated signal system. In this particular the electrical control has a decided advantage, in that one man with the proper arrangement of controllers can operate several stations in synchronism and that by using proper interlocks it can be made impossible for him to cause trouble by starting up in wrong sequence.

Another feature which makes the electrical drive of great advantage is that in starting such apparatus at the (beet) wheel, which has to be done frequently, the old style method of starting up this wheel was by means of a friction clutch, and the best of these clutches were bound to give trouble in time, especially if the clutch got wet. Electrical control here has been of great advantage.

Although there is no particular gain in the coal pile by the use of electrical power, there are great gains in flexibility, efficiency of control, and reliability, as well as saving in labor. However, these advantages will not be realized if we do not give considerable attention to the method of control and the system of distribution, in doing the best we can at reasonable cost. Although I do not want to lay down a fast and hard rule on fuse protection, still there has been a great deal of trouble in sugar mills—and I suppose on other installations operating under similar conditions as well—due to blowing of a single fuse on a three-phase circuit and then running for some time on a single phase and getting the motor heated up. Furthermore, although some designers have attempted to obtain simplicity by putting in hand switches and the simplest kind of control apparatus, this is not of so great an advantage, as appears on the surface, in operation.

The help we get now days is often inexperienced, and when we put even such a simple piece of apparatus as the compensator in the hands of such a man, he is liable to do considerable damage with it, especially when he operates it a great many times. It is very difficult to impress upon the inexperienced man such a simple proposition as throwing the compensator in quickly. He is more likely to want to "feel" the contacts in the endeavor to start up easily. Therefore, in many cases, it pays to go more or less to what we might call complications, and install push button control and automatic starting apparatus, which will impose upon the man who operates the various controls the very least possible responsibility.

CLOSURE.

Mr. Kermer: I want to point out that this paper was designed to give a general description of the beet sugar industry in America, to be read at a joint meeting of the Western Society of Engineers and the A. S. M. E. I have, therefore, evaded the chemical end

of the subject as much as possible, not that I believe it would not be of interest, but the time allowed would not be sufficient to consider this in detail.

Professor McCormick's statement regarding the modern filter press,—that the cloths can be washed without removing them from the frame,—is misleading. There are certain times during the season that we cannot clean the filter cloths by merely pumping water or an acid solution through them. It is necessary to take the cloth off the frame and wash it in a washing machine. This is especially true when we are slicing rotten beets, or having trouble with our carbonation.

No matter what kind of press is used, the press will be out of commission after a very short time if we have to deal with the above mentioned conditions. It requires a good deal of time to dress the frames of a modern filter press, due to the fact that the filter cloths must be sewed on, while with the ordinary plate and frame press, the filter cloth is merely hung over the plate without requiring any sewing or fitting. Professor McCormick's statement that the leaves in a modern press can be changed just as quickly as you can change the cloth on the old plate and frame press can only be due to inexperience in operation under varying conditions.

His statement that the white pan massecuite is dropped into the crystallizers is also misleading. As a matter of fact this goes direct to the mixer for the centrifugals. Only the brown or second sugar is sent to the crystallizers, after which it is handled as stated in my paper.

Apparently Professor McCormick did not understand the process at outlined in my paper. I did not state that the molasses was sent to the raw pan. Technically speaking, the mother liquor obtained from the white centrifugals (called the green) goes to the raw pan, hence to the crystallizers and then to the centrifugals. There the second sugar is separated from its mother liquor, which is called "molasses." This is a final product and cannot be reduced in the ordinary process. Only the Steffens or Osmosis processes, which are quite distinct from the straight sugar making process, are capable of extracting the sugar from the molasses. The amount of molasses produced is approximately 5 per cent of the weight of the beets, and should not contain over 50 per cent of sugar.

The sugar boiled from the "green," called the brown sugar, may be remelted and is returned into the process, or can be mixed with the thin juice.

It is self evident that if "molasses" (all the remaining impurities) were reintroduced in the process after a complete cycle, the amount of impurities would gradually increase, and, therefore, the juice coming through the factory would not be the same at all times, as Professor McCormick contends, but as a matter of fact, after a short time, it would be impossible to separate the sugar, and the extraction would become very low.

DISCUSSION BY LETTER

*Samuel A. Greeley**: I wish to compliment the author on this interesting and excellent paper and to thank the Western Society for the opportunity it has afforded engineers for learning so many interesting features about the important beet sugar industry. I have been particularly interested in beet sugar plants from the standpoint of sewage treatment. The sewage of a beet sugar plant is relatively large in volume and unusually strong. At a plant slicing 500 tons of beets per 24 hours, the sewage, pro-rated as to strength and volume, is equivalent approximately to that from a population of 75,000 or more. In the middle west where small streams are quite likely to have low flows during the fall, the problem of stream pollution becomes important, and already in two instances action has been brought by the state authorities. Thus, in some instances the problem of sewage treatment is an important part of the sugar industry. During the campaigns of 1917 and 1918, the writer has been operating a comprehensive sewage testing station to study the treatment of such sewages.

INDUSTRIAL SEWAGE PROBLEM

The problem of the treatment or disposal of industrial sewages is steadily becoming more important in this country. The general necessity for locating industrial plants reasonably close to the source of raw materials usually takes precedence over a location predicated upon the disposal of the wastes produced. As populations adjacent to rivers increase and as sanitary standards develop, public attention is directed toward the prevention of stream pollution and thus to the treatment of industrial wastes. Of recent years the regulation of the pollution of streams has been vested in the jurisdiction of federal and state authorities. Thus, problems of sewage treatment not contemplated in the original design have been brought to the attention of plant managers.

The treatment of industrial sewages has recently been attacked with much care. Up to the present time the problems studied have been those relating to the treatment of wastes from tanneries, packing houses, starch works, rubber plants, wool scouring plants and breweries. To a less extent the wastes from creameries and oil refineries have been studied, while beet sugar plant sewage has so far received the least amount of attention. The prime end of all of this work in this country has been particularly to abate nuisance; in other words to solve a sanitary problem rather than to recover valuable by-products. For many of these problems sufficient data is available to form a basis for the design of sewage treatment plants, although special local conditions frequently make it desirable to undertake special tests in small units in advance of the preparation of detailed drawings for large installations. It was from this view point that the testing station recently operated by the writer was built.

*Hydraulic and Sanitary Engineer, 64 W. Randolph St., Chicago, Ill.

PUBLIC POLICY

As yet no definite policy on the part of local, state or federal sanitary authorities has been formulated. This is undoubtedly due in part to the present lack of knowledge regarding methods of treating sugar wastes, and other industrial sewages. In some special instances where the wastes from an industry create offensive conditions in a small water course, complete treatment has been required by state officials, but usually with a provision for the installation of small units for test purposes in advance of permanent construction.

BEET SUGAR PLANT SEWAGE

In the process of manufacturing sugar from beets, comparatively large volumes of water are required. Records of the total sewage at three plants per thousand tons of beets sliced are shown in the following table:

TABLE 1—BEET SUGAR PLANT SEWAGE QUANTITY

Plant.	Gallons per 24 hours, per 1,000 tons of beets sliced.
A	3,640,000
B	3,340,000
C	3,250,000

These sewages naturally fall in two general classes. A chart indicating the beet sugar plant processes and the sources of sewage is shown in Fig. 1. In the first class are the waste waters coming from the flumes used in transporting the beets and the waste waters from the beet washing processes. These wastes are of comparatively large volume and contain large amounts of dirt, soil and other inorganic substances. Their contents of organic matter is comparatively low.

The second class of waste from a beet sugar plant includes those from the processes after the beets are washed, and consists principally of the waste from the diffusion batteries and the pulp presses. These wastes are less in volume than the first class, but contain very much larger amounts of organic matter both in suspension and solution. They therefore contain a larger proportion of those substances which are readily decomposed and which require larger amounts of oxygen or oxidation to a stable inoffensive condition.

A typical analysis of beet sugar plant sewage with those from several other industries is shown in Table No. 2. It should be noted especially that the sewage contains a large amount of total solids of which upwards of 85 percent is in solution. The oxygen demand is also relatively high and the sewage is acid. The organic substances in the second class of wastes originate from the beets and in

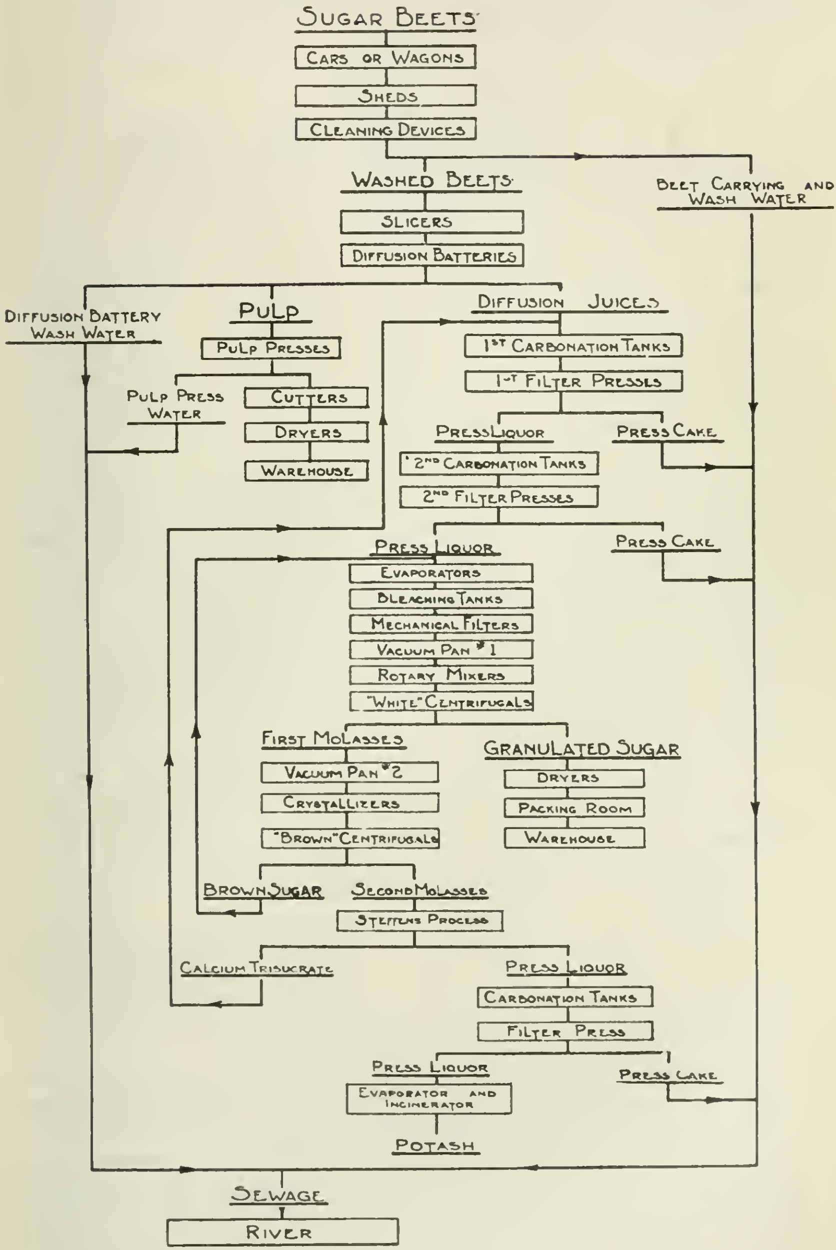


Fig. 1. Chart Showing Beet Sugar Plant Processes and Sources of Sewage

the beginning are largely cellulose and albumen. These substances are composed of carbon, nitrogen, sulphur, hydrogen and oxygen.

TABLE 2—BEET SUGAR PLANT SEWAGE—TYPICAL ANALYSES

(Parts Per Million.)

Items	Beet Sugar Plant (1)	Chicago 39th St. Sewer Domestic Sewage	Starch Plant	Packing Plant	Tannery
Solids				5,574	
Total	6,100			808	4,000
In Suspension	974	144	1,981.0		
Total Organic N	37.2	7.8	534.0	85	30
Oxygen Consumed	1,276	43	1,592.0	440	
Biological Oxygen		125			
Alkalinity as $CaCO_3$		212			253
Acidity	302				

There are also included in small quantities, iron, potassium, calcium and other minerals from the beet structure and other small amounts of earthy materials not removed in the washing processes. These elements appear as various products or combinations including some sugar, and are readily susceptible to bio-chemical change. These changes are the result of a number of processes produced by enzym action, by bacteria or by direct chemical action. The products of decomposition are numerous. In the absence of oxygen, marsh gas (CH_4) and sulphuretted hydrogen (H_2S) are produced. From the nitrogen present other substances form, some of which produce bad odors.

On account of the unusual strength and character of the wastes, their high oxygen demand and their relatively rapid decomposition their treatment must be approached with care.

At some places, both here and abroad, sewage treatment plants have been built which afford some experience and an indication of the efficiency of the various sewage treatment devices. Calmette (Director of Pasteur Institute, Lillie, France) states that if the diffusion battery wastes are diluted to 100 per cent with the beet wash water and then screened and settled, they can be treated on sprinkling filters at the rate of 1.07 million gallons per acre of filter per day, and a non-putrescible effluent produced.

German experience has followed more generally along the line of devices for treating the waste sufficiently for re-use in the plant, or for treatment on comparatively large areas of sandy soil.

In this country the most general treatment so far developed is in large settling ponds formed by building dykes about low land adjacent to the plans. This treatment, however, is entirely inadequate where the effluent is discharged into a stream of relatively low flow.

In one or two instances where stream conditions below the beet sugar plant have become offensive, additional treatment on

large areas of sandy soil has been undertaken with some measure of success. It is necessary, however, to give the sewage proper preliminary treatment by screening or settling and to provide sufficiently large areas of open sandy soil which are frequently not available.

SEWAGE TESTING STATION

From a study of the references to the treatment of beet sugar plant sewage here and abroad, and from a knowledge of the comparatively well defined sewage treatment process for domestic and other industrial sewages, a sewage testing station was built to study the behavior of the sawage from a large beet sugar plant in the middle west. At the outset it was decided to study the treatment of the waste from the diffusion battery and pulp presses as this was the smallest in volume and the most concentrated. Mixed sewage from these sources was taken at a rate of 75,000 gallons per 24 hours and split through a number of processes.

The sewage testing station comprised a fine mesh self-cleansing revolving screen, two settling tanks, two sprinkling filters, two sand filters, and three sludge beds. After screening, one series of settling tanks and filters was operated on straight sewage and plain sedimentation and the other series with chemical precipitation using lime as the precipitant. Later, studies were made of the wastes from the diffusion batteries and pulp presses, mixed with varying amounts of the beet carrying and washing water. This testing station has been operated during the campaigns of 1917 and 1918, twenty-four hours per day under constant chemical control. As yet, however, final results have not been obtained. A summary of some of the results is shown in the following table:

TABLE 3—TREATMENT OF BEET SUGAR PLANT SEWAGE—RESULTS OF TESTING STATION—OPERATION—PERCENTAGE REDUCTION

Items	Percentage Reduction from Crude Sewage by		
	Screens	Settling Tanks	Sprinkling Filter
Suspended Matter	12	50	70
Oxygen Consumed	22	38	

It has been found that a 30 mesh screen removes about 14,000 pounds of screenings per million gallons of sewage, these screenings containing about 90 to 95 per cent of moisture, depending somewhat upon the amount of wash water used. Chemical precipitation with lime appears to give better results than plain settling as it prevents excessive foaming. A removal of approximately 50 per cent of the suspended matter appears feasible. The results of filter treatment are not yet complete or available as the principal work upon them was done during the 1918 campaign. From time to time during the tests, special laboratory work has been undertaken to study the changes in the temperature, acidity and

biological oxygen demand of the sewage at various points through the treatment processes.

SUMMARY

Although in general it may be stated that sewage treatment processes are now reasonably understood, and for domestic sewages and some industrial wastes rates of treatment have been established, there is still much to be learned relative to the treatment of beet sugar plant sewages. Any further information of experience would be highly desirable as a matter of record. It is expected that the results of the present series of experiments can be made public in detail at a later date, although it may be desirable to run the station through another campaign, depending upon the results of the 1918 work, which have not yet been tabulated. Among the points to be determined are those of the proper admixture of diffusion battery and pulp press sewage with beet carrying and wash water, and the allowable rates of application of sewage to different types of filter after proper preliminary treatment, including the utilization of sandy soils of different characteristics as found locally available. In particular, however, the character of the stream receiving the sewage and other local conditions, including the use of the stream below the sugar plant, must be investigated.

The Present and Prospective Status of the Gas Industry

By S. W. Parr,
Professor of Applied Chemistry, University of Illinois.

Presented January 8, 1919.

AS I understand it, the chief interest of this organization centers in investigational work along lines primarily of importance to the gas industry. I have purposely omitted all reference to the carbureted water gas method, for in my opinion this process has seen its best days and is now on the decline, and rightly so in Illinois, because we have an almost unlimited amount of gas making coals within our state. Another reason for the certain end of this process is the fact that gas oil and fuel oil are becoming more scarce every day, and will continue to do so because we have eminent chemists striving to get the more valuable products out of the crude oil, leaving less of the products available as gas oil or fuel oil. Furthermore, at no time can the carbureted water gas process compare favorably with the by-product coal gas method in cost of gas production.

The somewhat overworked term "research" is thus at once brought forward, and for this, certainly in connection with gas interest, no apology is necessary.

Research in the industries in general is now assuming a role of tremendous importance and furnishes many striking illustrations of its timeliness and value. In the gas industry, however, this form of activity lags a little, especially on the chemical side. This seems somewhat strange when we recall that the greatest chemical industries the world has ever known or is ever likely to know are based directly and immediately upon coal tar products. We might naturally expect that more attention would have been given to the production of the "products," but here we are, with a running start on the second hundred years of gas manufacture in 1919, doing the same old things in the same old way, substantially as they were done by Le Bon in France and Murdock in London in 1807 and Peale in Baltimore in 1817.

In these days of evolution and revolution is it not proper that we scan the situation critically as to future developments, to indulge ourselves in speculating upon possibilities which are now latent and undreamed of: The taking of stock of what we have been doing and of what we might do if we knew how.

We shall not discuss all of the different problems affecting the gas industry, for that would mean the universe. That would take us into engineering and politics, into psychology and economics. We have neither the ability nor the hours for such a program. For our estimate of the present status, as also for our prognostications for the future, we shall stick rather closely to a few funda-

mental chemical facts. This greatly simplifies and renders very attractive our task. For the time being we are altogether oblivious to engineering and constructional or operating problems. We have no meters, no complaints and no franchise. Moreover, instead of talking about what we know, which would confine us within distressingly narrow and cramped limits, we have before us for discussion the boundless field of what we don't know. That indeed is implied in the very idea of research. It takes us beyond the borderland of our knowledge for untrammeled excursions into the unknown. With this freedom and expanse before us we enter what may be truly designated as the happy hunting grounds.

At this point it may be proper to make one further observation: It seems to me we need a sort of formula or prescription as a working basis for research. Whether actively engaged in such work ourselves or whether patrons or interested onlookers, if I were to outline such a specification, the first article would proclaim that for every real human need we should believe and proceed on the assumption that sooner or later there would be found a solution for it. Wherever the welfare and progress of society is involved there research is certain in the end to be rewarded. Or, in perhaps more general terms, let us say "anything that is highly desirable to do will eventually surely be done."

This implies supreme optimism. At the gateway to a program of research no pessimist should ever apply, no grouch or any man with the dyspepsia will do. Only those may qualify who conform to Pope's specification where "hope springs eternal in the human breast." This implies faith—faith even to the extent of believing in the possibility of the impossible. The qualification is well though somewhat facetiously covered by a Limerick which runs:

> There was a young man who asked, Why
> Can't I look in my ear with my eye?
> If I give myself to it, I am sure I can do it.
> You never can tell till you try.

Now to come somewhat more directly at the specific things of interest to the section. If I were asked to select a text or a creed or an article of faith for this organization I think I could not do better than offer the well-known quotation from an address by Sir William Siemens, delivered in 1881, which reads as follows:

"I am bold enough to go so far as to say that raw coal should not be used as fuel for any purpose whatsoever and that the first step toward the judicious and economic production of heat is the gas retort or gas producer in which coal is converted either entirely into gas or into gas and coke as is the case at our ordinary gas works."

If that was true in 1881 and if there was sufficient development at that time to warrant such a sweeping prophecy, then certainly today there is tenfold more reason for believing in the soundness of his forecast. Note especially his statement "that raw coal should not be used *as fuel* for any purpose whatsoever."

This proposition, whether visionary forecast or sound theoretical doctrine or actual obligation for technical procedure, I thoroughly believe in. If this is accepted as a major premise, then we are ready to formulate a first corollary to our creed as embodied in the above quotation. It is this: The prime function of the gas industry is that of a purveyor of fuel. It is true that the primary idea in the gas business was to furnish light, and in that capacity it has had a fine record and an honorable career for more than 100 years. But does not the gas industry sometimes take on the attitude of a man who has been long and intently gazing at a fan-tail flame or an incandescent mantle? When he turns his face away, even though he closes his eyes, he can still see only the hazy outline of a fan-tail flame or an incandescent mantle.

Before entering upon further discussion of this proposition it will be well to outline another proposition, perhaps another corollary to what has preceded. It would be this: The interest which we represent has been misnamed "the gas industry." As a matter of fact we are or should be engaged in the manufacture of certain commodities, in connection with which gas is produced incidentally and as a by-product. The other commodities, therefore, should pay the freight, the overhead, the fixed charges and the profits. Anything therefore in addition to which the gas could bring in would be all to the good.

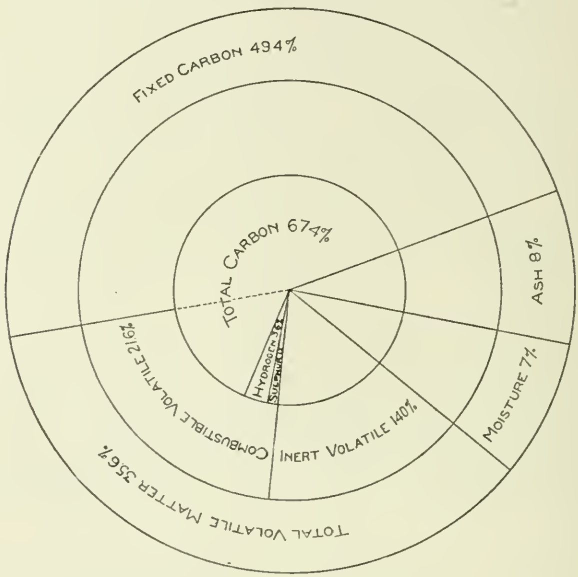
If these things could be actually realized then the goal of a gas company's ambition would be, not a dollar and a half rate, but rather a half dollar rate in order that the larger yield of these "other" profit-producing things might be in evidence.

These are altogether radical, possibly also altogether heretical statements. Let us see if they have any scientific basis or evidence of any sort tending to furnish proof, even in any mild degree of their sanity.

First, then, as a help toward an analysis of the situation, let us turn to an analysis of the raw material with which we are working. An analysis possibly of a little different sort, or perhaps we should better say an analysis with slightly different interpretations from those to which we are usually accustomed. It will also serve our purpose to base our considerations upon an Illinois coal. In the diagram accompanying this article, the various components are represented as consisting of ash, water, volatile matter and fixed carbon or coke. Let us in this connection recall the fact that these components are not present in the coal as such, but we may obtain them in the forms designated by subjecting the raw coal to a red heat. That is to say, there is substantially no free carbon in the raw coal; that practically all of it is combined chemically with hydrogen or with hydrogen and oxygen. Similarly there is no volatile matter in the original coal; that which we get out of the coal as volatile matter we make by disrupting the solid material and rearranging the atomic relations in such a way that some of these remain in the gaseous form.

The order of these new arrangements admits of almost infinite variation and every order has its own peculiar property and value. Naturally also any of the changes in order cannot take place when the elements are in solid form, such as exists in the natural coal, nor are any changes to be looked for in that portion of the material that remains in the solid form as coke. It follows, therefore, that these numerous interchanges of position must take place in that portion which is mobile, that is, the volatile matter.

It is a little strange, I think, that in this zone of potential variations, considering the possible values involved and the readi-



Analysis of Illinois Coal—Average of Ten Illinois Coals, Showing Constituents in Relative Proportions.

ness with which an almost endless number of changes may be brought about, that we have gone along for an even hundred years maintaining one single set of conditions and producing again and again the same brief list of products which also in many respects lead all others in inferiority as to intrinsic worth.

For more conveniently illustrating some of these characteristics, let us refer to the chart as drawn, wherein we may let the outer zone represent the first 100 years of practice. The component parts, very briefly described, would run about as follows:

First, water. A rather high percentage of it, say 8 to 12 per cent exists in Illinois coals. However, in itself having neither value, nor yet any harm, except as it has to be included in the freight charges and paid for as coal in the final settlement for the raw material.

Second, volatile matter. With something over five cubic feet

of fixed gas to the pound to its credit, plus certain condensible products in the way of ammonia water and tars of somewhat indifferent value.

Third, coke. Not always of a quality to excite enthusiasm on the part of users, but still a salable commodity, if its properties and virtues are adequately set forth by propaganda methods.

The second zone is one of prognostication, of possibility, of research, possibly of a new development and, let us hope, of some progress in accomplishment during the second one hundred years to which we are looking forward.

First, there is here also water, no better and no worse than before. Second, there is the volatile matter, which we have already indicated in the area of modification and of new possibility. It has been pretty well demonstrated by investigators both in this country and in England that under suitable conditions this area may be made to yield, first, and doubtless of co-equal if not of greater worth, not tars of the ordinary type, but more properly oils with an absence of inert and inferior compounds, and a wealth of potential development and modification almost bewildering to contemplate: a hunting ground for the investigator, without parallel in both interest and importance. For example, in volume it is fully double that of the tars as ordinarily produced, yielding from 23 to 25 gallons per ton from Illinois coals and as high as 45 gallons from coals of the Eastern Kentucky type. Instead of a specific gravity of 1.2 these condensates may be produced with a specific gravity that scarcely reaches 1. They are, therefore, high in the lighter fractions, low in their pitch contituent, and carbon in the free state is practically absent. It is hardly necessary here to enlarge upon the advantages which may reside in this material. The simple enumeration of the qualities already given suggests features of possible interest to the dye and automobile industries, to the wood preserving interests, to road work, etc. But not the least in importance to my mind is the readiness with which these oils lend themselves to decomposition and rearrangement into other substances and other values. Studies in the field of such transformations have been greatly stimulated in recent years.

By way of illustrations we might recall what has been accomplished in a different field but upon material having even less susceptibility to change. The hydrogenation, for example, of oil and fats such as cotton seed oil and lard, has resulted in the production of other compounds of greatly enhanced value and popularity in the culinary art. Similarly it has been demonstrated that hydrogen may also be introduced into these oils or condensates from the volatile products of coal decomposition, so that a door seems here to be opened whereby we may increase the amount of the lighter and more volatile oils. This retention or introduction of hydrogen into any compound lowers its specific gravity and also its boiling point and these two properties are fundamental for that type of fuel upon which the automobile and the airplane industry are based.

On the other hand, hydrogen as a gas in the free and uncombined state is rather poor material. We measure its heat value per unit volume, which is low, at the foot of the list, 326 B. t. u. per cubic foot. But kept in the fluid form it tops the list—over 62,000 B. t. u. per pound. For example, metaxylene has a boiling point of 139. If we introduce hydrogen or substitute hydrogen for one of the methyl radicals, we shall have Toluene with a boiling point of 110. If we replace the other methyl by hydrogen we have benzene with a boiling point of 80. Just what the limitations are in this process of hydrogenation no one can now say. The field is too new for making even an intelligent forecast, but suppose the light oils of the benzene type which now show a yield of from 2 to 3 gallons per ton could be increased to 10. The potential motor spirit from the coal output of Illinois would be about one billion gallons.

If Scotch shales can be worked at a profit for their oil and ammonia alone, where the oil content seldom exceeds 20 gallons per ton, why not Illinois coal with a yield of 25 gallons, with the ammonia as well as gas and coke for by-products?

The above discussion, however, by no means exhausts the interesting possibilities which lure the investigator. I will only mention one other connected with this volatile zone and that is the behavior of the sulphur. We know pretty well what its habits have been for the past 100 years. I believe that in some respects it could be induced to mend its ways. By proper handling, for example, a very considerable proportion of the sulphur can be induced to go along with the tar, thus lowering the amount left to distribute itself in the coke and gas. Then again, practically all of the sulphur which is going off with the gas leaves the coal at a temperature below 600 degrees C. The question at once arises, could we fractionate the gas even from Illinois coals and draw a line between the first portion, which we might call sour or sulphur gas and the next portion which is sweet or sulphur-free. The line of demarcation would come somewhere very soon after the first cubic foot per pound is discharged. Certainly some interesting possibilities connect themeslves with these facts.

I cannot leave this fruitful zone of volatile material without one further reference, and that is to the line of demarcation between the "rich" and the "lean" gas. As you well know, this occurs somewhere along about 650 or 750 degrees C. I raise the question as to what is the good of the lean gas? To my mind it is more than a figure of speech to say of it "the game isn't worth the candle." It is here that the highest heat for the longest time must be applied, where both time and heat are vital operating factors. Then, too, hydrogen again is chiefly what you get out, and certainly, here again, hydrogen in some other form or combination is worth more than when in the form of gas. Here is where the improvement in the properties of coke is to begin.

It seems to me as it must to you that we have only touched

the fringe of the possibilities that await the persistent investigator in the field of gas engineering.

DISCUSSION.

W. M. Willett: Prof. Parr stated that there was about two feet per pound of gas that could be taken off at such a temperature, that almost all the sulphur would go with it, and then also toward the final point of distillation there is left in the coke some ten per cent of volatile matter. After making these deductions, about what would be the yield per pound of coal?

Prof Parr: Not over three feet per pound. That will strike any gas man as being ridiculous and absurd, and we will stop right there, but before leaving that point, consider this fact. Three feet of gas per pound instead of five or five and one-half is not so bad if it has twice the value and if the yield of tar is high and if you can get it in half the time.

R. B. Harper: In the earlier part of this talk a question was brought out as to why the gas industry had not advanced during the last two hundred years, and it was shown how little we know about the whole proposition. I got the impression that this is a method for producing by-products, rather than for producing gas. With the production of three feet per pound of coal, I should like to hear from Prof. Parr about what would be the average composition under the heat value. We should be able to deduct a rich gas. We might have the material we have had in the past. If it is largely refined it might be very contagious to produce such a gas. The feature about sulphur, I think, is a very good one.

Prof Parr: Some of the samples, covering the first foot of gas per pound, have been so surprising that we almost hesitate to believe our own results, but we have almost pure gas. In fact, taking the natural gas, you can almost figure the percentage, and this comes nearer to that condition; all of which, if we are willing to let our imaginations run along theoretically, we might, in our production of coal of the anthracite type, find the same elements. It is evidently some high composition of marsh gas that gives character to the heat that it carries. Whether that is the type of gas to distribute to consumers is another question. If I were to figure out a community of fifteen thousand people, it seems to me that I should take some of this coke which would make rain water gas and run the plant with that, mix it half and half with this rich gas, and if this coke was any good we would all want it. The profits are in the coke and oil, and you would be glad to get rid of the gas at fifty cents a thousand.

C. C. Hotchkiss: The thought that occurred to me in regard to the ultilization of this Illinois coal, if means could be found for utilizing it, is that it would be a great advantage, especially in this matter of congestion and other difficulties. Just what is the situation and is this process being followed to any extent? Further, what are

the prospects of developing Illinois coal in large quantities in by-product coke ovens?

Prof. Parr: Between our present state and the industrial possibilities there is only this difficulty, the feature that has not been determined: Can we bring a mass of coal up to this temperature and have it clear the oven? In our small oven, we were through with the process, not having run above a temperature of 750 degrees. We have had experience enough to know that the successful laboratory experiment is far from the industrial situation. Before we know how or just what we were doing, we had an oven that carried 1,000 pounds and we pretty nearly tore the university building to pieces to get the stuff out. Perhaps it is just as well to state these facts, that we do not know whether or not the coal will push until we build an oven not less than sixteen inches.

J. F. Unger: What was done in England in making coalite on these low temperatures?

Prof. Parr: Coalite was promulgated in England in about 1916 or 1917. The company was capitalized for a large sum. It seemed a proposition scheme, but they had a little data to go on. I was interested in that because that was about the same time that the first article came out in the University Bulletin. Coalite has been revived and there is a company in England where they claim to be operating. Regarding the interests in New York that some of you are familiar with, putting out a substance known as carbocoal: Mr. Smith used to have a small plant that reached a commercial stage, as I understand. In all essentials, as far as the principles are concerned, it conforms to what I have said, in that it does not go above 700 degrees temperature. It is their method of carrying out the process. If it has the industrial opportunity to do it, perhaps it will be done, but the above processes seem to offer some question as to its possibilities. We have solid and semi coke, and there were two or three different attempts made along these various lines. There have been more failures than anything else. I know of nothing that is on the verge of actually putting out this material unless it is the Waldo Coal Company of New York.

Proceedings of the Society

Meeting No. 1033, March 10, 1919.

This was a meeting of the Bridge and Structural Engineering section and was attended by 130 members and guests. G. A. Haggander, chairman of the section, presided. The paper of the evening was prepared by W. H. Finley, president, Chicago and Northwestern Railroad, describing the Chicago and Northwestern Railroad terminal elevator on the Calumet river. On account of the absence of Mr. Finley the paper was presented by F. C. Huffman, principal assistant engineer, C. & N. W. Railroad. The paper was illustrated by numerous slides and gave the design and construction features of the elevator, which was of reinforced concrete. It also described the mechanical apparatus and equipment for rapid handling of grain and the protection of grain in storage.

Meeting No. 1034, March 17, 1919.

This was a general meeting of the society. There were present 81 members and guests. E. J. Noonan, chief engineer, Chicago Terminal commission, presented a paper on the Chicago terminal situation. This was illustrated with lantern slides. The Chicago Terminal commission, in their study of the railroad terminal situation in Chicago, looking toward the simplification of the terminals and a readjustment of the railroad property, has prepared a tentative solution of this large problem. This was embodied in the paper by Mr. Noonan, including the coördinated work of the City Planning commission.

Meeting No. 1035, March 24, 1919.

This was a joint meeting of the Electrical Engineering and Mechanical Engineering sections of the Western Society of Engineers and the Chicago section of the American Institute of Electrical Engineers. The meeting was attended by 243 members and guests. C. E. Lord, chairman, Chicago section, A. S. M. E., presided. Arthur H. Young, manager of industrial relations department of the International Harvester Company, presented an address on the subject of "Industrial Personnel Relations." This included an outline of the plans recently adopted by the International Harvester Company for coördinating the employe with the management in industrial problems of that corporation. Additional papers were presented by Mr. Tyler of Montgomery Ward & Co., and Mr. Cunningham of the Republic Flow Meters Company. Prior to the presentation of the paper a moving picture entitled "The Outlaw" was presented, which illustrated the progress of safety engineering. At the close of the discussion light refreshments were served.

Meeting No. 1036, March 31, 1919.

This was a special meeting of the society under the auspices of the committee on public affairs, R. F. Schuchardt, chairman. The meeting was attended by 113 members and guests. A statement was presented by the secretary, outlining the various bills pending before the Legislature, which are of interest to engineers as citizens, viz.: State constitutional convention, Illinois deep waterways, better city administration, city planning, public utilities commission, and licensing of engineers and architects. Jas. J. Barbour, state senator, gave an outline of the procedure of the state legislature and its attitude towards these important measures. B. H. Peck, electrical engineer, Public Service Commission, gave a resume of the problems before the commission, as they are affected by the increased cost of materials and labor and the resulting changes in rates. Douglas Sutherland, secretary, Civic Federation of Chicago, described the difficulties of our present municipal administration and the advantages to be gained by non-partisan election of eldermen, increasing the term of aldermen from two to four years and providing for the appointment of a mayor by the city council to be the city manager. H. K. Holsman, American Institute of Architects, discussed the housing bill now before the legislature and indicated the necessary revision of this bill before it can be satisfactory.

Edgar S. Nethercut, *Secretary.*

Book Reviews

Practical Ship Production. By A. W. Carmichael. First edition. 252 pages, 6 by 9 inches. 101 illustrations, drawings and figures. Bound in cloth and published by the McGraw-Hill Book Co., Inc., New York and London. Price, $3.00.

When the call came for ships and more ships this country seemed ill prepared to meet the emergency. It soon developed, however, that there were plants in nearly every port ready to be expanded into yards suitable for the tremendous demands made on them. There were available also a certain number of reliable and competent workmen, and, best of all, many skilled designers, naval architects and constructors who were eager to put their knowledge and experience to the test. Training men for the special tasks of ship construction began immediately, and the results, ships, are now in service.

It is obvious that time would not permit of training men from the very beginning. The problem was more properly to adapt tradesmen to the specialized work of ship building. This book, therefore, deals with few of the theoretical features of the subject, but goes into the details of the more important principles of ship design, with which every naval architect should be familiar, and describes the various processes in connection with the building of ships. Production from available plans is given the preference over theoretical preparation of new plans.

This book will assist technical men to transfer their activities from various other engineering professions to those of the marine engineer and naval architect. It should also be of value to those workmen in ship yards who have a wide knowledge gained from actual experience, to fit themselves for higher positions.

Some of the scope of the book may be gained from the various chapters on Requirements of Ships, General Description of Ships, Structural Members of Ships, Design of Ships, Shipyards, Preliminary Steps in Ship Production and the Building of Ships. C. A. M.

United States Artillery Ammunition. By Nathan Vaill, Managing Editor *American Machinist.* 98 pages 8¾ by 11½ inches, illustrated. Bound in cloth. Published by McGraw-Hill Book Co., New York. Price, $2.00. Compiled for the use of shopmen, engineers and manufacturers. Covers steps in the manufacture of the following:

3″ Common Shrapnel
3″ Common Shells (High Explosive)
3″ Naval Shells
3.8″ to 6″ Shrapnel and High Explosive Shells.
6″ Naval Shells
3″ to 6″ Cartridge Cases

The book describes in detail the operations of machines and men in the fabrication of shells and shell casings. Descriptions of final protective coatings are included. The use of photographs and well executed perspective drawings adds materially to the interest of this work.

Inspection tests and gaging are outlined and these are very interesting.

The reader is impressed by the great predominance of lathe work in this class of manufacture. The description of the various lathe operations shows the great progress made in this class of work. Aside from the use of lathes, the drill press is the only machine that is greatly used.

The time studies and details of operations recorded in this book are well arranged and should prove of great value to the manufacturer or engineer interested in this field of work. The work is covered in a most thorough manner. Many of the machine operations are interesting and unusual.

The engineer busily at work will find that spare time spent in reading this book is well spent. Just at present it has a special timely interest.

The methods of handling metal and treating metal surfaces should be of value in other mechanical fields. H. E. H.

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The Comparative Economics of Cantilever and Suspension Bridges

By DR. J. A. L. WADDELL, M. W. S. E.
Consulting Engineer.

To be presented September 15, 1919.

UNDER the title "Suspension Bridges and Cantilevers—Their Economic Proportions and Limiting Spans," Dr. D. B. Steinman in 1911 issued a little book in the Van Nostrand Science Series; and in 1913 he produced a second edition of it with a few revisions and the addition of four folding plates.

In that treatise he draws the conclusion that "the critical span at which the suspension bridge becomes economically superior to the cantilever bridge is 1,670 feet." His calculations were made for a structure carrying four steam railway tracks between trusses and two exterior sidewalks on the lower deck, and a roadway with electric railway tracks between trusses on the upper deck, the total live load for the trusses being 18,000 pounds per linear foot, of which 12,000 pounds were for the steam railways. His profile shows bare bed rock, which, under the approaches, is approximately horizontal and a few feet above extreme high-water level. He figured his cantilever structures for main openings of 1,000 feet, 1,500 feet, and 2,000 feet, and his suspension bridges for main openings of 1,500 feet, 2,250 feet, and 3,000 feet.

While recognizing the value of Dr. Steinman's work and giving him due credit for his laudable energy and ambition, the writer doubted the correctness of the main conclusion just mentioned, and in his treatise on "Bridge Engineering," issued in 1916, he wrote concerning it as follows:

"In order to evolve a mathematical demonstration of the problem, he (Dr. Steinman) had to make numerous assumptions more or less approximately correct. Without checking all of his mathematical work, it is evident that the professor has made as fair a comparison as he could; but his assumptions were so numerous and approximate that his conclusions must be taken with a liberal allowance for variation.

EDITOR'S NOTE: These papers are published in advance of publication in order to give an opportunity for the preparation of discussion. The discussion will be printed in a subsequent number of the journal.

"All these facts affect materially the question at issue, and it is probable that, if the changes implied were incorporated, the span length for equal cost found by the investigator would be considerably greater."

For a number of years the writer has had the desire to settle this economic question; but the amount of labor involved had always appeared appalling. In truth, it was so, because Dr. Steinman spent most of his spare time for two years in making the computations for his investigation.

It is true that the writer could easily have figured the weights of metal and the costs thereof for cantilever bridges by employing the diagrams which he prepared for his papers on "Nickel Steel for Bridges," and "The Possibilities in Bridge Construction by the Use of High-Alloy Steels," most of which diagrams were published in these papers; but not until after he had written Chapter XXVII of "Bridge Engineering" did he possess any quick method of computing the weights of metal and the costs of suspension bridges. In that chapter are presented for the first time a number of formulas from which, in conjunction with the numerous diagrams in Chapter LV of the same treatise, can be found quite readily the approximate weights of metal for all portions of suspension bridges.

In April, 1918, for the first time since the issuing of his book, the writer found leisure to make the contemplated economic investigations. They occupied all of his spare time for a month and a half, representing altogether some 300 hours of steady figuring. As in the case of his paper on "The Possibilities in Bridge Construction by the Use of High-Alloy Steels," he did all of the computation work entirely unaided, checking the results himself, but relying for their correctness mainly upon the regularity of the platted curves.

As his data on weights of metal in cantilever bridges were primarily for double track railway structures, his first investigation was made for that class of bridges, using the live loads, impact, and specifications indicated in the two previously-mentioned papers. For convenience of comparison, he assumed Dr. Steinman's unit prices for metal in place, but for substructure estimating he adopted the method which he has empolyed for many years, viz., using a unit price for concrete above low water, another for the mass of the pneumantic caissons with their superimposed cribs below low water, another for the corresponding mass below the same in box cribs filled with concrete resting on piles, and a price per lineal foot for those portions of the said piles projecting below the bases of the cribs. These unit prices are as follows:

Shafts and walls	$15.00 per cu. yd.
Mass of pneumatic caissons with their cribs.....	25.00 per cu. yd.
Mass of box cribs, including enclosed portions of piles	20.00 per cu. yd.
Piles projecting below base of crib............	1.50 per lin. ft.

The unit prices for metal in place were as follows:

Wire cables	12.5c per lb.
Nickel steel	8.0c per lb.
Carbon steel in spans	5.6c per lb.
Carbon steel in trestle approaches	5.0c per lb.

The costs of the railway tracks, the roadway pavements with their reinforced concrete bases, and the reinforced concrete sidewalks have been ignored when computing the total costs of structures, because they are common to the two classes of bridges compared.

In making the computations for this paper, the writer took the liberty of adopting several short cuts, such as assuming squared instead of rounded ends for all piers, using generally the method of "end areas" instead of that of the "prismoidal formula" when calculating volumes of masonry, carrying out quantities of materials and total costs to rather large limited units, and estimating costs of certain parts by proportions from the previously computed costs of similar parts of other structures. All these and many other short cuts for avoiding labor are perfectly legitimate when making comparative estimates, provided that they affect alike the compared types of construction, as they do in this case.

In the plotted curves of the diagrams accompanying this paper the points enclosed by small circles indicate the main-span lengths of cantilever bridges, for which the total cost of structure has been computed; and the points enclosed by small squares indicate the lengths of computed spans for suspension bridges. It will be seen that no curve was drawn through less than three located points, and in many cases the number was four or more. The regularity of all the curves proves that there was no error of any magnitude in the figuring which located the points thereof. It does not mean, however, that the writer's calculations contained no errors. Unfortunately, several mistakes crept into the work, but the plotting invariably pointed them out and led quickly to their satisfactory correction.

In the diagrams the abscissus represent main-span lengths in feet, and the ordinates show the total costs of structures in dollars, the recorded units being millions.

As the tabulated estimates of cost prepared by the writer do not make interesting reading, some of them have been placed in an appendix to this memoir. It seemed hardly necessary, however, to record *all* of the cost estimates made, because so doing would cause the paper to be unnecessarily long.

In figuring the weights of stiffening trusses for suspension bridges, the writer made an important modification in one of the formulas given in Chapter XXVII of "Bridge Engineering." Equation 15 thereof has been employed without change, when wind stresses are ignored; but the following formula *for the weight per*

foot of both trusses has been added to cover the case where the effect of the wind load is considered:

$$T = 2.8 \left\{ 3.9 \frac{M_m}{d\,s} + \frac{3.26\ V_m}{s} \left(\frac{p^2+2d^2}{d\,p} \right) \right\} + \frac{8\ P\ L^2}{11\ b\ s}.$$

The corresponding equation when the wind stresses are ignored is:

$$T = 2.8 \left\{ 5.06 \frac{M_m}{d\,s} + \frac{3.26\ V_m}{d\,s} \left(\frac{p^2 + 2d^2.}{d\,p} \right) \right\}.$$

The greater of the two values of T given by these equations is, of course, the one to use in the estimate of total weight of metal.

The division of total metal weight between carbon steel and nickel steel was made by the writer's judgment, based upon the curves in his two beforementioned papers and upon the assumptions of material distribution adopted when preparing the suspension bridge computations. No error of any magnitude exists because of this assumed distribution, although, of course, the method employed is only approximately correct.

Whenever a proper weight curve for cantilever structures was not available, the writer fell back upon the general curves for weights of metal in trusses and laterals that record the various double panel weights in cantilever arms and anchor arms as multiples of the corresponding double panel weight of the suspended span, which general curves were first given on Plate X of "De Pontibus," and afterwards were reproduced in Fig. 25-j of "Bridge Engineering."

In establishing the general assumptions for the layouts of both cantilever and suspension bridges, with one exception they were made as favorable as possible for each type, that exception being that, for the sake of appearance, the anchor arms of each cantilever structure were made of the same length as that of the cantilever arms, viz.: 0.3125 of the main opening, instead of the more economic value of 0.2 thereof. Concerning the correctness of the last claim for economy there is some dispute in the profession; but of this matter, more anon.

In the suspension bridge layout the backstays were not used to support side spans, but were run by approximately right lines to the anchorages. This is the most economic layout possible, because a steel trestle approach is always cheaper than any layout of truss spans that can be made, not only because it requires less metal, but also because the unit prices thereof erected are somewhat smaller.

The main piers of all the cantilever bridges and most of those for the suspension structures were designed as two pedestals with a reinforced concrete wall between, this wall extending a short distance below extreme low water mark. It was found, however, in the case of the combined four track railway and highway suspension bridges, that it was just as economic to use a continuous piér,

because of the four points of support required by the tower columns, hence that feature of construction was adopted.

The method employed for finding the quantity of concrete in the anchor pier for a cantilever bridge was to compute the maximum uplift, multiply it by two, and divide the product by the weight of one cubic foot of concrete, taking due cognizance, of course, of the buoyant effort of the water on all submerged portions thereof. If the volume thus found would work up into a properly shaped pier, well and good; but if not, an additional amount was provided.

The method of proportioning the anchorages for suspension bridges, when the foundations were solid rock, was to make each one quite long and narrow, high in the rear and low in the front, and to let the line of pressure reach the base exactly on the edge of the middle third thereof. In case the foundation were piles, a similar shape was used, but it was necessary to keep the load on each pile of the front row down to forty tons.

When piles were employed to support the main piers, the limiting load per pile was taken also at forty tons, exclusive of the effect of wind pressure. The piles used were all assumed to be one hundred feet long.

The limiting widths of structure were as follows: In cantilever bridges one twenty-fifth of the main opening; in suspension bridges one-twentieth thereof, measuring between central planes of exterior columns over main piers; and between central planes of stiffening trusses one-thirtieth of the main opening. As a matter of economy, in some of the cantilever structures the distance between truss planes was made as small as practicable for the suspended span, and was gradually widened out to a maximum over the main pier, and then gradually reduced to a minimum over the anchor pier.

The economic lengths for the cantilever structures were taken as established twenty years or more ago by the writer when preparing the MS. of "De Pontibus," viz.: For the suspended span, three-eighths of the main opening; for each cantilever arm, five-sixteenths of the main opening.

As before stated, the length of the anchor arm, for the sake of appearance, was made the same as that of the cantilever arm, although some metal would have been saved by assuming it shorter.

In the suspension span, also, economic dimensions were used, viz.: one-fortieth of the length for the truss depth, and one-ninth thereof for the deflection of the cables. In order to provide proper splay for the latter (when splay was required), the tower width, as before indicated, was made one-twentieth of the main opening. This militated very slightly against the suspension bridge, because, in the substructure, it increased the cost of only the walls between the pedestals of the main piers, the increase being a bagatelle in comparison with the total cost of the said substructure.

The first estimates prepared by the writer were for double track railway bridges; and he assumed, to begin with, an opening

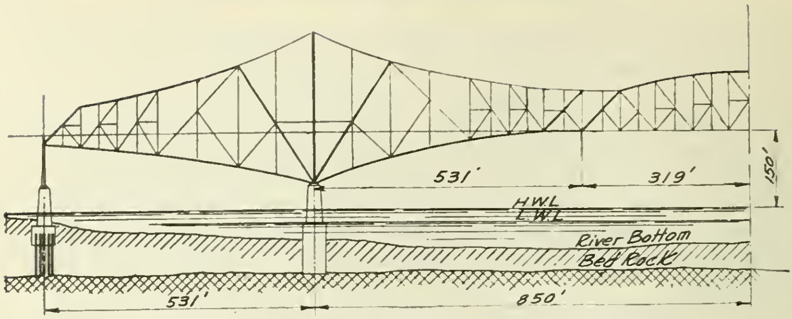

Fig. 1. Layout for 1,700-foot Span Cantilever Railway Bridge.

of 1,700 feet, which is approximately Dr. Steinman's span-length for equal cost. The profile adopted for this crossing is shown in Fig. 1 and Fig. 2. It will be seen that there is a difference of twenty-five feet between high water and low water, that the river bed is some fifty feet below the latter, and that the bed rock is one hundred feet below the same for condition No. 1. In condition No. 2 there is no bed rock, hence the piers and anchorages are supported on piles. As the writer had anticipated, the result of the calculations showed a large difference in favor of the cantilever structure, the total costs being \$4,120,000 and \$7,980,000. These figures are for condition No. 1, in which all piers and anchorages were assumed to be sunk by the pneumatic process to bed rock.

For condition No. 2, in which there is no bed rock within reach of the piles, the corresponding figures were \$4,420,000 and \$7,030,000.

The suspension bridge anchorages resting on piles were found to be so much cheaper than those resting on bed rock that it was concluded to adopt them for condition No. 1, and to assume the piles to be driven to bed rock. In order, however, to make the comparison perfectly fair, the anchor-piers of the cantilever bridge were also figured as resting on piles driven to bed rock. The result of this change was a large reduction of the difference in cost between the two types of structure compared, as shown by the following totals: \$4,080,000 and \$6,387,000. These are the costs which are plotted in Fig. 3.

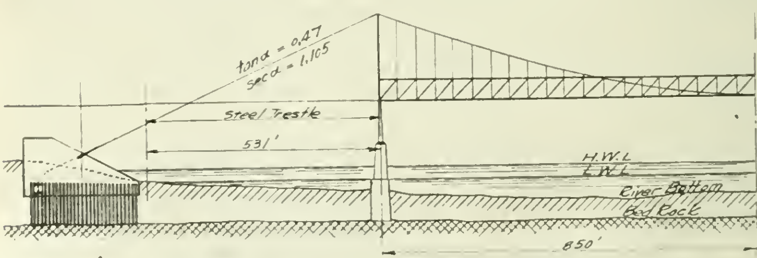

Fig. 2. Layout for 1,700-foot Span Suspension Railway Bridge.

After noting the large difference in these total costs, the writer decided to test a twenty-four hundred foot opening, thinking that

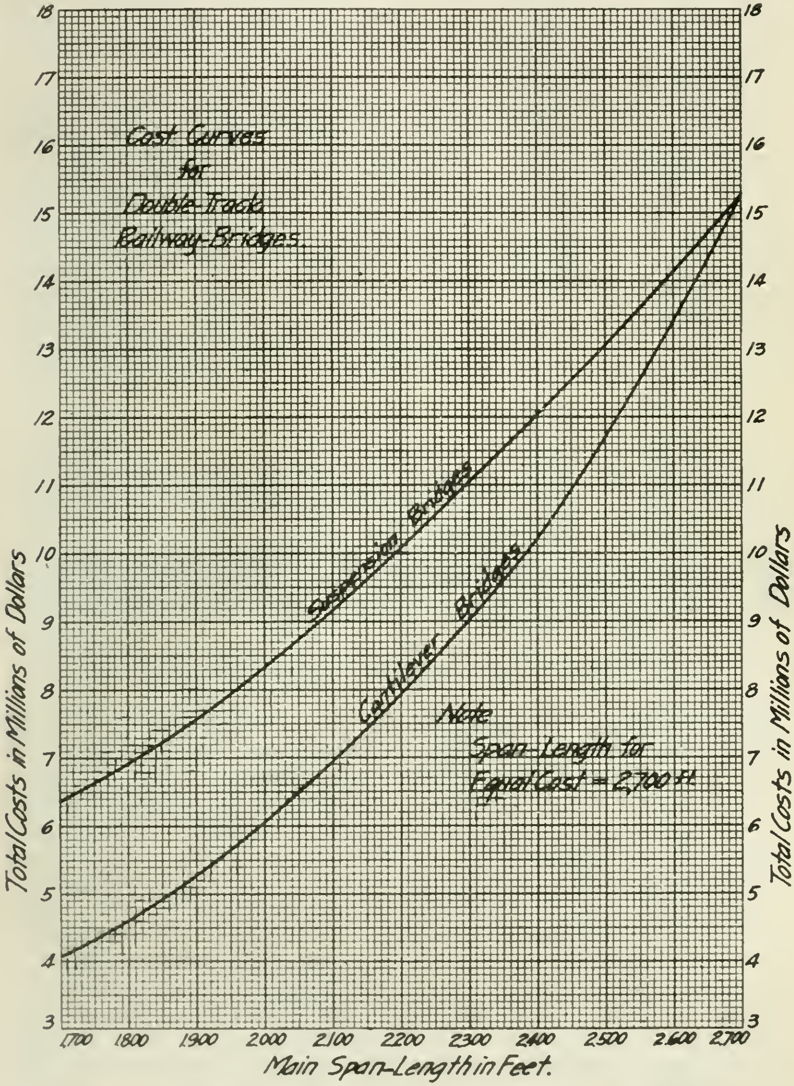

Fig. 3. Cost Curves for Double Track Railway Bridges.

surely for such a long span the suspension bridge would be the cheaper. The bed rock was kept at the same elevation as before, the only difference in the profile being that the width of river was increased, as shown in Fig. 4 and Fig. 5. It was decided, in order

to save labor, to do no further computing upon the basis of main piers resting on piles; but all anchor piers and anchorages were assumed to be thus supported, as in the final estimates for the 1,700-foot spans. Much to the writer's surprise, the results showed the cantilever structure to be still the cheaper, the total costs being $10,210,000 and $12,033,000.

Then an opening of twenty-seven hundred feet was tested, the result being $15,269,000 for the cantilever bridge and $15,259,000 for the suspension bridge. This shows that for double track railway bridges of nickel steel, the span length for equal costs of cantilever and suspension bridges is 2,700 feet, or one hundred feet longer than the greatest advisable length recommended by the writer in his paper on "The Possibilities in Bridge Construction by the Use of High-Alloy Steels."

In order properly to plot the curves in Fig. 3, it was necessary to compute the cost of a cantilever bridge having a span of

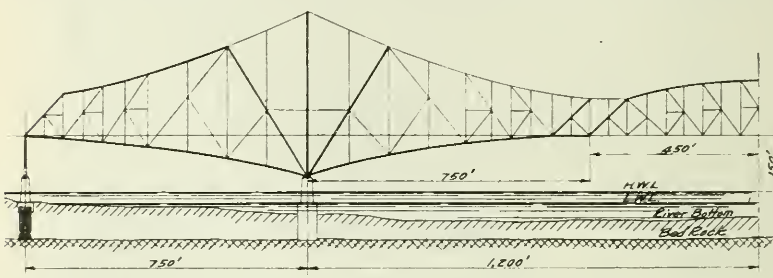

Fig. 4. Layout for 2,400-foot Span Cantilever Railway Bridge.

2,050 feet. This gave four points on the curve and enabled it to be sketched in satisfactorily, after which it was easy to draw the corresponding curve for the suspension bridge.

In order to make as good a showing as practicable for the suspension bridge, as far as the layout is concerned, it was decided to assume that the bed rock comes quickly to the surface in the vicinity of the main piers and runs back thereafter at an elevation of about ten feet above high water in the manner adopted by Dr. Steinman. This assumption reduces greatly the costs of the anchorages of the suspension bridges and to a much smaller extent those of the anchor piers of the cantilever structures. The effect of this change on the cost curves in shown in Fig. 6. From it there will be observed that the span length for equal cost has been brought down to about 2,570 feet, showing that the change made in the bed rock profile has effected comparatively little variation in this span length.

The result of the preceding calculations differs so fundamentally from that of Dr. Steinman that the writer found it necessary to study carefully in detail the doctor's various assumptions and estimates, so as to discover the reason or reasons for the great

difference — amounting to over one thousand feet. The following variations between his data and estimates as compared with those of the writer were found:

First: In his contilever bridges Dr. Steinman makes the ratio of length of suspended span to that of main opening vary from 0.5 for 1,000-foot openings to 0.4 for 2,000-foot openings, while the writer two decades ago showed the economic ratio to be 0.375; and, as previously mentioned, he (Dr. Steinman) makes the length of the anchor arm 0.4 of the main opening instead of about one-half of that amount.

Second: Dr. Steinman's bridges carry both railway and live loads, while the writer's are for railway traffic only.

Third: Dr. Steinman's suspension bridges have side spans supported by the backstays, while in the writer's layouts these spans are replaced by steel trestle approaches entirely disconnected from the main structure.

Fourth: Dr. Steinman uses a tension intesity of working stress of 20,000 pounds for carbon steel and one of 30,000 pounds for nickel steel, while the writer's practice has been to employ, respectively, 16,000 pounds and 28,000 pounds.

Fifth: Dr. Steinman ignores entirely the effect of impact on trusses, while the writer allows for it. In the very long spans this cuts very little figure, but such is not the case for the shorter spans.

Sixth: Dr. Steinman's estimated costs for substructure not only exceed greatly those of the writer, but also the ratios of

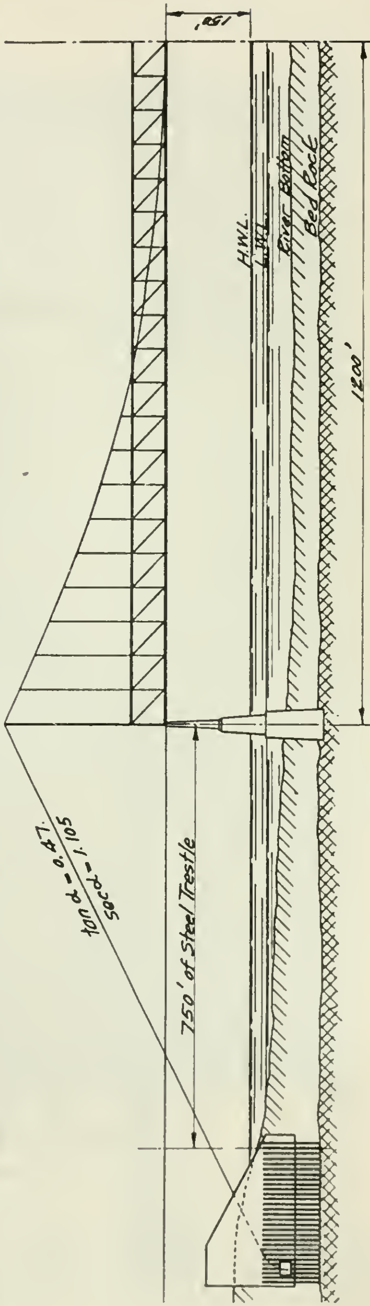

Fig. 5. Layout for 2,400-foot Span Suspension Railway Bridge.

division thereof between main piers and anchorages are fundamentally different from his.

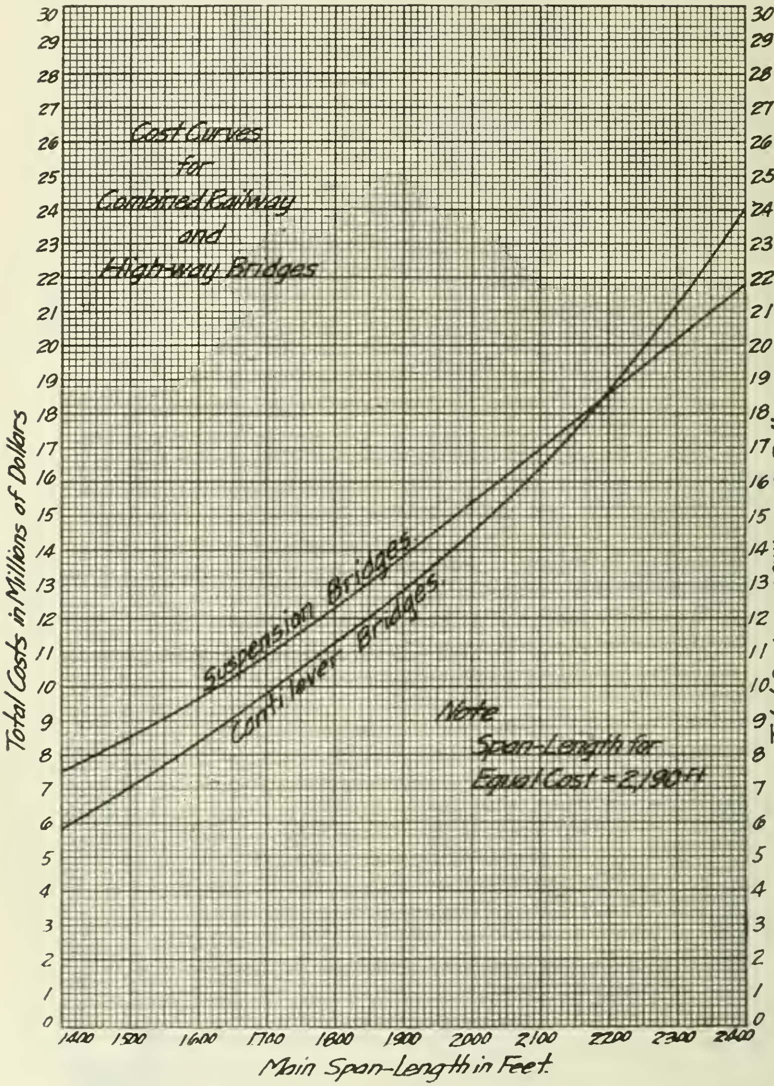

Fig. 6. Modified Cost Curves for Double Track Railway Bridge.

Seventh: In his cantilever-bridge estimates Dr. Steinman divides the metal into five groups, viz.: Suspended span, cantilever arms, anchor arms, towers, and anchorages, but some of the total amounts for these groups are greatly out of proportion.

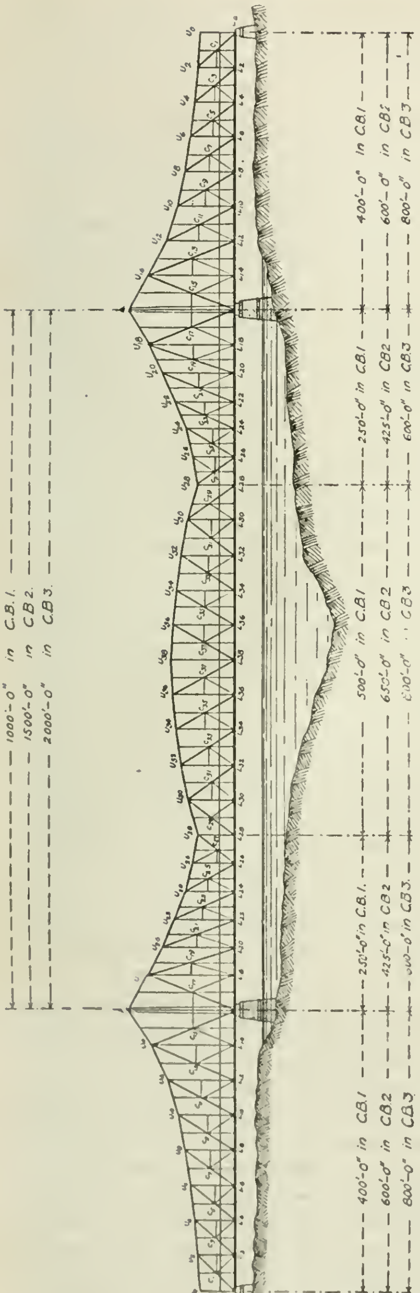

Fig. 7. Dr. Steinman's Layouts for Cantilever Bridges.

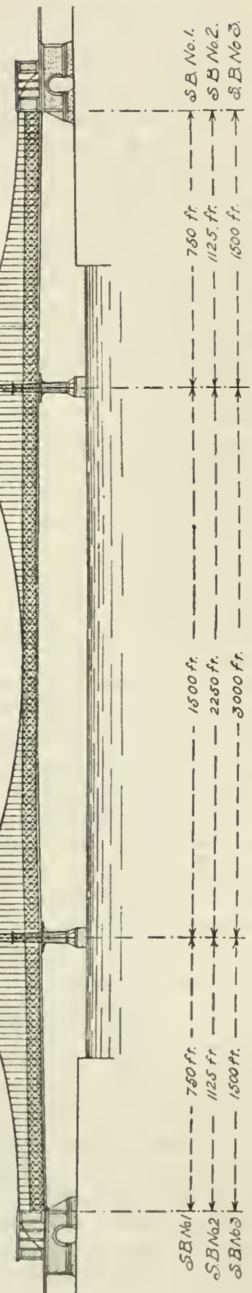

Fig. 8. Dr Steinman's Layouts for Suspension Bridges.

A dissertation upon the first, sixth, and seventh variations may throw some light upon the subject; and, to make it properly, it became necessary to reproduce here Dr. Steinman's two layouts, as shown in Fig. 7 and Fig. 8.

Is it not evident by a glance at Fig. 7 that the long anchor arms, passing over dry land, must be uneconomic as compared with steel trestle work, which, as is well known, is the cheapest kind of metalic structure? It is true that Dr. Steinman, Dr. Burr, and, possibly, other writers have shown mathematically that the economic length of the anchor arm is four-tenths of the main opening; but such questions cannot be solved by mathematical analysis, for it is impracticable to consider by equations the many variables in the make-up of an anchor arm, as well as simultaneously a trestle approach. Dealing with this point, the writer made the following statement in "De Pontibus": "When, however, the problem is to determine the economic length of anchor arm for a fixed distance between main piers, the result will be quite different; because, within reasonable limits, the shorter the anchor arm the smaller will be its total weight of metal, and because trestle approach is much less expensive than anchor arm. It would not, for evident reasons, be advisable to make the length of anchor arm less than twenty per cent of that of the main opening, or say fifteen per cent of the total distance between centres of anchorages. With this length there would probably be no reversion of stress in the chords of the anchor arm, even when impact is considered. Generally, though, the appearance of the structure will be improved by using longer anchor arms than the inferior limit."

If there is no other way to settle this question, the writer is willing to determine it beyond all possibility of doubt by preparing, for insertion in his résumé of the discussions of this paper, actual designs and estimates of quantities and costs for the anchor arm layout of Fig. 7, and for a corresponding layout in which the exterior half thereof is replaced by steel trestle; but this would involve considerable trouble and an expense amounting to several hundreds of dollars. If this method of determination be insisted upon, it will be adopted; but perhaps the following *a priori* observations will be sufficiently convincing:

First: About 29 per cent of the total weight of the trusses and laterals of this anchor arm is included in its outer half, and the average weight per foot of this portion is about 71 per cent of that for the entire structure. Applying this to the already computed weights of a double track railway cantilever bridge having a 1,500-foot opening, and using the unit costs of materials in place as stated, makes the average value per linear foot of the outer half of the anchor arm \$640. The weight of metal per linear foot for a double track steel trestle one hundred and forty feet high is 4,200 pounds, and its value is \$210, to which should be added not to exceed \$5 per linear foot for the cheap concrete pedestals required to raise the column feet a short distance above the rock founda-

tion. This shows that the trestle costs only one-third as much as does the outer half of the anchor arm.

Second: While it is conceded that the remaining portion of the anchor arm may weigh somewhat less per foot than it would as an independent arm, the difference will be small for the following reasons:

(a) As the moment over the pier is the same for all lengths of the anchor arm (because it comes entirely from the loadings on the cantilever arm and the suspended span), the weights of metal in the truss members lying near the pier will not differ greatly in the two cases.

(b) While the negative stresses due to the uplift will be increased by the halving of the resisting lever arm, on the other hand the direct live load stresses will be greatly diminished because of the halving of the span length, these two effects tending to offset each other.

(c) With the short anchor arm, the stresses in the outer diagonals (as well as in all the other main diagonals) and in the top chord members will always be tensile, hence eyebars can be used for these members, thus effecting a great saving; because, owing to the increase in sectional area (to allow for rivet holes) and to the weight of the details, it takes nearly fifty per cent more metal to build a riveted tension member than is required for the corresponding eyebar or eyebars.

(d) While it is true that the short arm produces a greater uplift and, consequently, necessitates a heavier anchorage, it must be remembered that the value of an economically designed anchor-pier is very small in comparison with the cost of the rest of the structure. Again, it must not be forgotten that with the long arm there is positive as well as negative loading on the anchor pier, and that, in consequence, it is possible that there would be no difference worth mentioning in the cost of the two anchor piers.

It seems to the writer that, in view of the preceding, it ought to be evident without further calculation that a length for the anchor arm equal to two-tenths of the opening ought to be decidedly more economic than a length twice as great.

In respect to the substructure, Dr. Steinman in his design for his 1,500-foot span, four track steam railway and highway cantilever bridge found the cost of two main piers to be $1,262,000, and that of two anchor piers $1,032,000; while the writer found for his nearest corresponding double track, steam railway bridge $827,000 and $161,000. While it is entirely impracticable to compare these figures, because of fundamental differences in both the loading and the foundation conditions, it is evident that Dr. Steinman must have made some serious mistake in his calculations when he caused the costs of his main piers, with their pneumatic foundations, and his anchor piers, resting on bare, dry bed rock, to be so nearly alike; because the latter generally are insignificant affairs when compared with the former. This same error exists in the other two

cantilever bridges which he has computed; for in his 1,000-foot span he found, respectively, $876,000 and $524,000, and in his 2,000-foot span $2,153,000 and $1,994,000. This matter will receive additional attention later on.

In respect to his division of weights of metal in superstructure, Dr. Steinman recorded the following:

Weights of Metal in Pounds.

Main span in feet.	The susp. span.	One cant. arm.	One anchor arm.	One tower.	One anchorage.
1,000	8,738,000	6,551,000	9,697,000	5,987,000	785,000
1,500	15,550,000	16,951,000	20,566,000	17,479,000	1,794,000
2,000	28,964,000	39,750,000	40,851,000	40,158,000	3,374,000

Referring to the item of weight of one tower in both the 1,500-foot-span and the 2,000-foot-span structures *it exceeds the total weight of metal in the suspended span as well as that in the cantilever arm, and is but little less than that in the excessively long anchor arm.* Surely this cannot be correct! That tower consists of two braced columns, the load on each of which is composed of the vertical components of the stresses in the two upper chord members meeting at its top, and these are not extraordinarily great. Had the upper chords been run horizontally from inner hip to inner hip, the column stresses would have been zero, barring those due to their own weight and to an insignificant wind pressure on the columns themselves only.

It is practicable by means of Plate X of "De Pontibus" to find approximately what the weight of the tower would be. Let us test it for the 1,500-foot span structure. If W is the double panel weight of metal in trusses and laterals for the suspended span, then the corresponding panel weight over the pier is $1.8 \times 3.0\ W =$ 5.4 W. Of this not more than two-thirds can pertain to the columns, or 3.6 W. As W is equal to 1,240,000 pounds, the tower weight (3.6 W) would be only 4,464,000 pounds, instead of the 17,479,000 pounds which Dr. Steinman finds. Such glaringly great irregularities as these upset the entire economic comparison and render its results worthless. Moreover, all these variations from correctness combine to militate against the cantilever structure. On the other hand, though, the assumption of side spans supported by the backstays militates against the suspension stucture.

In view of the preceding, the writer concluded that it would be necessary to compute quantities and plot cost curves for cantilever and suspension bridges of the type and loading assumed by Dr. Steinman, adhering as closely as practicable to his general features of layout, character of metal used in the various parts, weights per foot of floor systems and lateral systems, and cost per foot of trestle approaches; but differing with him in the following particulars:

First: Raising the grade of the structure so as to afford a

vertical clearance of 150 feet above high water, and lowering the elevation of main pier foundations to 35 feet below low water. This is more in accordance with probable actual conditions than is indicated by the profile in Fig. 7.

Second: Substituting steel trestle approaches for the side spans shown in Fig. 8.

Third: Adopting the most economical type of substructure for each case.

Fourth: Adopting a length of anchor arm equal to 5/16 L instead of 0.4 L.

With these premises the writer computed the costs of cantilever and suspension bridges for openings of 1,500 feet and 2,400 feet, and found that the span of equal cost lies between these limits. Then he figured for a 2,000-foot span. This gave him three points on each curve, as shown in Fig. 9, besides which, he estimated in detail by proportion the costs for several other openings and plotted the results of these also. Fig. 9 shows that the span-length for equal cost is about 2,190 feet, instead of the 1,670 feet found by Dr. Steinman—a difference of over 500 feet.

It will be interesting to compare the substructure costs found by Dr. Steinman and those found by the writer for like spans and practically the same general conditions, as recorded in the following table:

Main Span-Length and Character of Structure.	Cost in Dollars of the Main Piers.		Cost in Dollars of the Anchorages.	
	Steinman.	Waddell.	Steinman.	Waddell.
1,000-foot Cant......	876,000		524,000	
1,500-foot Cant.....	1,262,000	506,000	1,032,000	290,000
1,500-foot Susp.....	1,330,000	440,000	2,428,000	1,222,000
2,000-foot Cant.....	2,153,000	660,000	1,944,000	310,000
2,000-foot Susp.....		600,000		1,920,000
2,250-foot Susp.....	1,835,000		4,174,000	
2,400-foot Cant.....		926,000		357,000
2,400-foot Susp.....		880,000		2,400,000
3,000-foot Susp.....	3,017,000		6,995,000	

Of the preceding nine cases there are only three which can be directly compared, viz., the 1,500-foot cantilever, the 1,500-foot suspension, and the 2,000-foot cantilever, although other comparisons might be made approximately by interpolation. It will be noticed that Dr. Steinman's main piers cost two or three times as much as those of the writer, his anchor piers for cantilevers from three and a half to six times as much, and his anchorages for suspension bridges about twice as much. This gives further proof of the statement previously made to the effect that his entire economic investigation is incorrect and that the deduction which he makes therefrom concerning the span length for equal cost is wrong.

In thus criticizing Dr. Steinman's little book, the writer does so merely because he feels that the profession should not be left

in error on such an important point as the comparative economics of cantilever and suspension bridges. Some time in the not very distant future there are going to be built in this country many long span bridges; and it behooves engineers to know in advance the economics of the different types of structures applicable thereto. Dr. Steinman deserves great credit for his energy and courage in attacking such a stupendous problem at such an early date in his professional career, without any records of weights at his disposal, and before he had had any actual experience in bridge work. In undertaking such an immense task he set a splendid example to other young engineers; and the incorrectness of his conclusion is no blot whatsoever upon his professional record. It would be well for engineering if there were in its ranks many more young men possessing the attributes of energy, ambition and love for hard work to the same extent that he does. Such men will be badly needed in every branch of technics, if our profession is to take the high position in the community to which it is entitled by its importance to mankind.

Dr. Steinman can console himself with the reflection that he is not the only engineer who has devoted an entire treatise to the production of a wrong conclusion, for several decades ago an eminent French professor of engineering published a large book dealing with the economics of truss bridges, basing his calculations upon such incorrect premises that the result of his work was of no real value to the profession.

Comparing the results of the preceding calculations, as shown in Fig. 3 and Fig. 9, it will be noticed that the span length for equal cost is much less for the combined railway and highway type of structure than for the strictly railway type. The reason for this is that in a modern highway bridge the proportion of dead load to live load is much greater than it is in a railway bridge, because of the large weight of the pavement, the supporting slabs, and the concrete footwalks. In the stiffening trusses of a suspension bridge it is generally the live load only which causes stresses that influence the sectional areas of the members, the dead load having no effect thereon whatsoever, but in a cantilever bridge it is the total live load plus the dead load which does so, with sometimes a little assistance from the wind load; hence it is evident that the smaller the proportion of live load to total load the more favorable it is for the suspension bridge. On this account, in strictly highway structures, the span length for equal cost will be much shorter than those thus far determined. Not knowing what the length would probably be, the writer figured the costs of the two types for 1,500-foot, 1,200-foot, and 1,000-foot main openings, using carbon steel only; and from the results of the computations he plotted the curves in Fig. 10. From this diagram it will be seen that the span length for equal cost is about 1,000 feet.

Recognizing that this investigation would not be complete without preparing a set of computations for strictly highway struc-

tures of nickel steel, the necessary calculations were made for a 1,000-foot span of each type, the result showing almost exactly

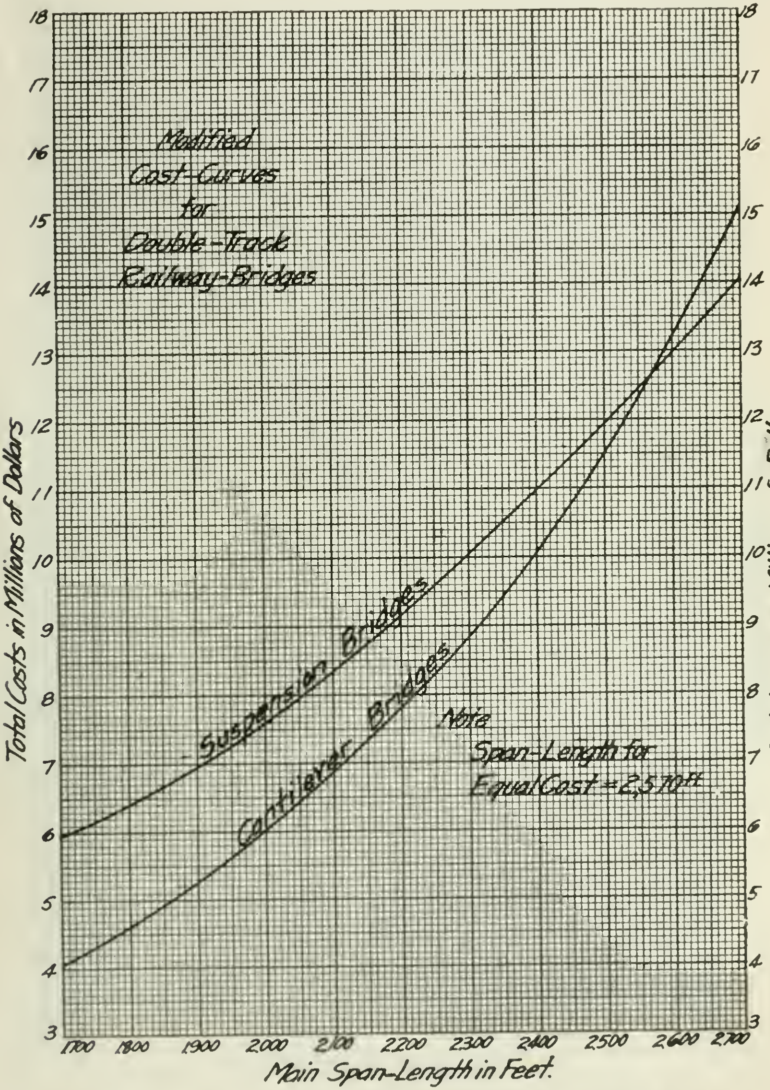

Fig. 9. Cost Curves for Combined Railway and Highway Bridges of the General Type Computed by Dr. Steinman.

equal costs. This indicates that the strength of the steel used does not modify the span length for equal cost in highway structures, although changing the totals of the estimates.

These highway bridges are of the same kind as that adopted as standard by the writer in his late paper on "The Economics of

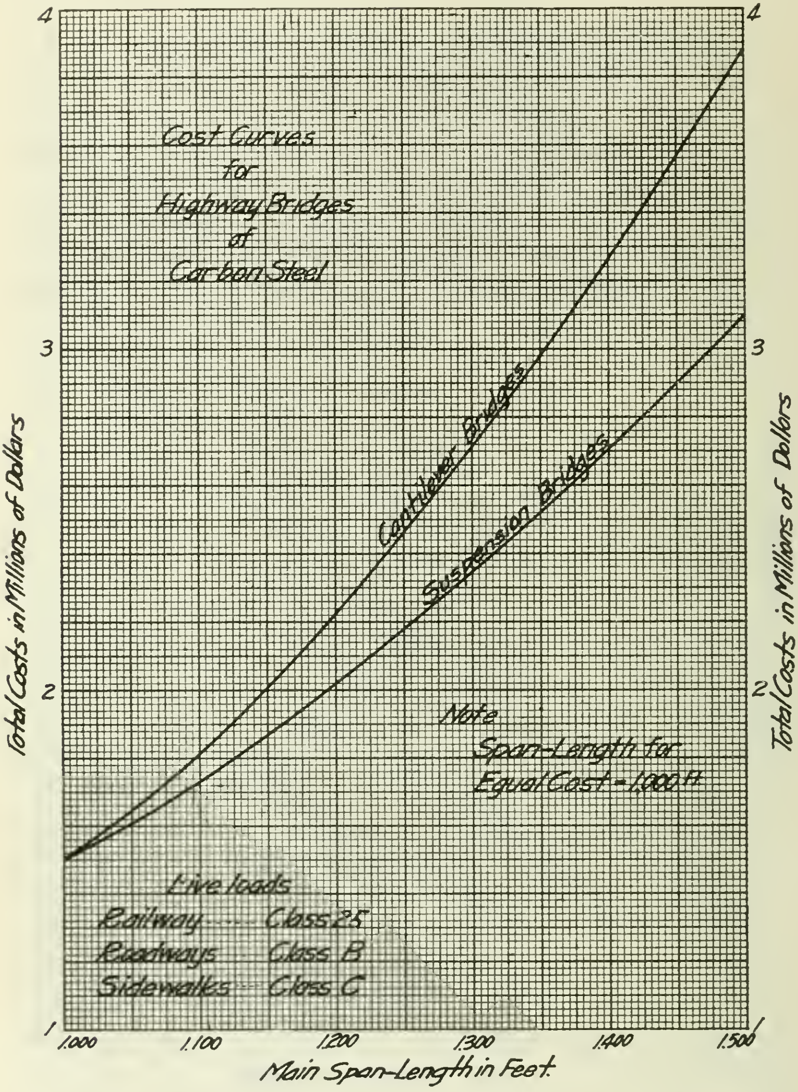

Fig. 10. Cost Curves for Highway Bridges of Carbon Steel.

Steel Arch Bridges," viz., a deck about 60 feet wide, out to out, composed of a paved roadway 42 feet wide, resting on a reinforced concrete base, and having a doube track street railway at the middle, and two 8-foot wide, reinforced concrete sidewalks. The live loads

for the floor system are class 25 for the electric railway, class B for the rest of the roadway, and class C for the sidewalks. Class A over the full width of the deck was employed for the trusses.

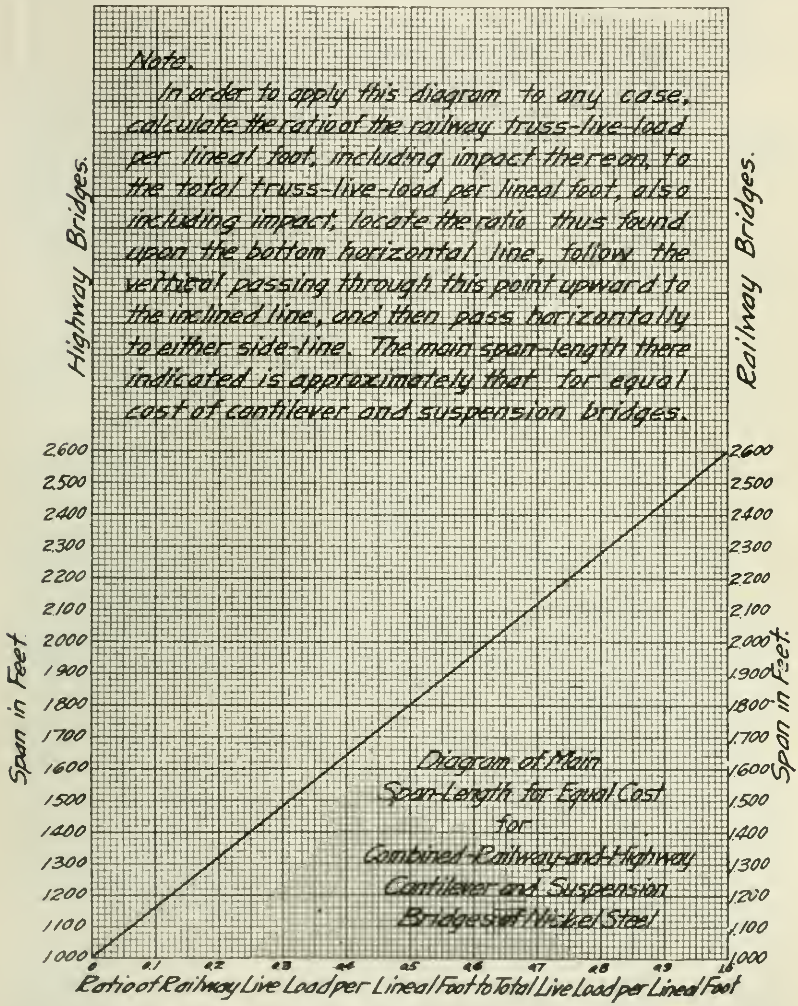

Fig. 11. Diagram of Main Span Lengths of Equal Cost for Combined Railway and Highway Cantilever and Suspension Bridges.

Estimates of weights of metals and costs thereof for some of these highway bridges are given in the appendix to this paper.

RESUME OF INVESTIGATION

First. For exclusively railroad bridges, the economic limit for

the cantilever type of structure, or, in other words, the main span length for a cost equal to that of the corresponding suspension bridge is that length which requires four and a half pounds of metal to carry one pound of live load.

Second. For modern highway structures, carrying also incidentally electric railway tracks, this limit is 1,000 feet.

Third. For combined railway and highway structures the limit is intermediate between the limit for railway structures and that for highway structures, the interpolation being done in direct proportion to the ratio of railway truss live load to total truss live load.

This may be expressed by formula thus: If G is the span length of equal cost for strictly railway bridges, and R is the ratio of railway truss live load to total truss live load, then, for combined railway and highway structures the span length for equal cost will be given aproximately by the equation:

$$S_e = 1{,}000 + (G - 1{,}000)\,R.$$

For instance, if $G = 2{,}700$ feet for nickel steel railway bridges and $R = \frac{2}{3}$,

$$S_e = 1{,}000 + 1{,}700 \times \tfrac{2}{3} = 2{,}133.$$

This checks fairly well with the value shown in Fig. 9, where

$$R = \frac{12{,}000}{18{,}000} = \frac{2}{3}.$$

Fig. 11 is a diagram from which can be found at a glance the span length for equal cost for any proportionate combination of railway and highway live loads, under the assumption that nickel steel is employed for the principal portions of the structure. In case, though, that carbon steel alone be used, which is unlikely, the limiting span length for cantilever construction is to be taken at about 2,000 feet.

While it was not intended to do any figuring concerning the comparative economics of cantilever and suspension bridges when alloy steels having higher elastic limits than 60,000 pounds per square inch are employed, it was surmised that the span length for equal cost for strictly railway bridges will not differ essentially from the limiting lengths for cantilever main spans determined by the writer in "The Possibilities in Bridge Construction by the Use of High Alloy Steels," viz.:

For $E = 70{,}000$ pounds per square inch............. 2,780 feet
For $E = 80{,}000$ pounds per square inch............. 2,910 feet
For $E = 90{,}000$ pounds per square inch............. 3,030 feet
For $E = 100{,}000$ pounds per square inch............. 3,140 feet

It is possible that the writer is not entirely justified in making this surmise, because computations might show that the span length for equal cost does not exceed 2,700 feet, no matter how high may be the alloy of steel used. It seemed hardly worth while to spend much time in figuring upon this question before a high alloy of steel satisfactory for long span bridge building is found; never-

theless, as a matter of curiosity, it was decided to test a main span length of 2,900 feet, for steel having an elastic limit of 80,000 pounds per square inch, and assuming that the cost of that metal in place is 9 cents per pound.

As shown in the detail in the appendix, the comparative figures of cost for the two structures are as follows:

Cantilever bridge	$15,720,000
Suspension bridge	15,233,000

However, had the price of the alloy steel been taken at 8 cents per pound, the same as for nickel steel, the cost estimates would have been as follows:

Cantilever bridge	$14,448,000
Suspension bridge	14,856,000

As these last figures reverse the previously found economics of the two types, it is evident that for bridges of high alloy steels the span length for equal cost is vitally dependent upon the pound price of the said alloy steel, the lower it is the more favorable is it to the cantilever structure. In view of the fact that at present no one has any idea of what the cost per pound will be for high alloy steels used in future long span bridge construction, it will be well to adopt temporarily as correct the writer's before mentioned surmise, viz., that in alloy steel bridges carrying railway loads only, the span length for equal cost is that for which, in the cantilever bridge, there are required four and a half pounds of metal to sustain one pound of live load.

The writer recognizes that a change in the assumed conditions would modify somewhat all the previously found span lengths of equal cost for both carbon steel and nickel steel bridges; but he does not believe that the variation will be material—say not to exceed two or three per cent in any case for any one fundamental change, or five per cent of any probable combination of changes. For instance, if the main piers rest on piles instead of going to bed rock, this will militate a little against the suspension structure, increasing slightly the span length for equal cost. The same effect occurs if the pound price for steel cables be increased without changing the pound prices for the other metals, and vice versa.

If the unit prices for substructure be decreased, the result will be favorable to the suspension bridge, because, while the main piers will be affected about alike, there will be a greater saving in the anchorages of the suspension bridge than in the anchor piers of the cantilever structure. Let us see what effect it would have to reduce the prices of all concrete work five dollars per cubic yard, thus bringing them close to the lowest limits for truly first class construction that have existed in periods of national depression.

In the railroad bridges of 2,700 feet span, the reduction in total cost of substructure would be $473,000 for the cantilever bridge and $928,000 for the suspension bridge, making the total costs, respectively, $14,796,000 and $14,330,000. Performing the

corresponding reduction in prices of substructure for the 2,400-foot spans gives, for the total costs, respectively, $9,877,000 and $11,-196,000. Plotting these points on a cross section diagram and joining them properly by very slightly curved lines shows that the span length of equal cost is reduced from 2,700 feet to 2,640 feet. This is no material amount, indicating, as it does, a variation of only 2.2 per cent.

The writer trusts that the discussion of this paper will be so thorough that the long mooted question of span lengths of equal cost for cantilever bridges and suspension bridges will be finally settled, so that, when the building of long span bridges in America takes a new start, as it is sure to do before long, it will be practicable in any case to determine readily in advance what type of construction ought to be adopted.

Addendum.

The preceding was written in the summer of 1918. A year later the author was called in by some prominent citizens of Detroit to make a study of the governing conditions for a proposed highway and street railway bridge over the Detroit River, practically on a line joining the business centers of the cities of Detroit and Windsor, and to determine upon the best type of structure to adopt. A few days of investigation led to the conclusion that a single span of 2,500 feet, crossing the entire river in the clear between harbor lines, would be obligatory; and, accordingly, the layout and the approximate cost calculations were made for a suspension bridge. It became necessary to obtain pound prices for structural metal (both nickel steel and carbon steel) and wire cables in place; and they were procured through the author's New York office with the following results:

Carbon steel erected..................	7.0c per lb.
Nickel steel erected....................	9.0c per lb.
Cables erected	23.0c per lb.

The last figure was simply staggering! Surely, such an enormous price can be only temporary, for the great difference between it and the other two figures is altogether illogical. Nevertheless, it shows the possibility of an abnormal price condition existing long enough to affect temporarily the economics of cantilever and suspension bridges. It is not likely that there can ever be a worse condition than the one at present governing; consequently, the author has recast for existing unit prices the estimates of cost made for the preceding investigation, and has found the following results:

The span of equal cost for highway bridges has been advanced from one thousand feet to exactly twelve hundred feet; that for the particular combined bridges investigated has been increased by one hundred and seventy feet; but that for the steam railway bridges has been augmented only sixty feet. The reason for the smaller increase in the last case is that, in cantilever structures

the weight curves, and consequently the cost curves, rise very rapidly at a span of twenty-seven hundred feet, because such a length is really a little beyond the truly practicable limit for that style of bridge.

These variations are somewhat greater than the maximum which the author anticipated when writing the penultimate paragraph of his paper; but at that time he never would have deemed it possible that such a great variation in unit prices of structural steel and wire cables could hold as that which exists today; nor does he now consider it possible that it can be made to last for any great length of time.

In making the Detroit-Windsor Bridge study, a practical proof was given of the usefulness of the preceding paper. No copy of "Bridge Engineering" was available for making an estimate of the cost of the suspension bridge and its approaches, but a copy of the paper was at hand, and, as a rough estimate was required immediately, the following procedure was adopted, it being recognized at the outset that all the assumptions made therein were upon the side of safety, and that, consequently, the resulting figures of cost would be somewhat too great:

Referring to Fig. 10, the curve for costs of suspension bridges was extended on an enlarged cross-section sheet to a span of 1,700 feet, at which length the spans on Fig. 3 begin. The cost thus found was multiplied by the average of the ratios of the unit costs of all substructure and superstructure materials in place for present conditions and the conditions assumed in the paper. Then, referring to Fig. 3, it was noted that the cost of a 2,500-foot span suspension bridge and its approaches is almost exactly double that for a similar 1,700-foot span with its approaches; hence the cost just found was doubled, and to the result were added the cost of the entire flooring from entrance to exit of structure, an allowance for the greater length of the approaches involved, and the approximate cost of either elevators or an escalator and a stairway at the Detroit approach.

Later, a more exact estimate of cost was made from the various data in "Bridge Engineering," the result being some five or six per cent less than that of the first approximation. This more exact estimate was computed in a single working day. Without the aid of the book mentioned, it would probably have required as many weeks of figuring as it actually took hours thereof, in order to obtain results of equal accuracy.

Appendix

The following are detailed estimates of cost of some of the structures computed for this investigation:

RAILROAD BRIDGES.

1,700-foot Span Cantilever Bridge.

Nickel steel, 30,670,000 pounds at 8c	$2,453,600
Carbon steel, 11,392,000 pounds at 5.6c	638,000
Total cost of metalwork	$3.091,600

Main Piers.

Shafts and walls, 11,580 cubic yards at $15	$ 173,700
Caissons, 26,140 cubic yards at $25	653,500
Total cost of main piers	$827,200

Anchor Piers.

Shafts and walls, 5,860 cubic yards at $15	$ 87,900
Bases, 1,740 cubic yards at $20	34,800
Piles below bases, 25,800 lineal feet at $1.50	38,700
Total cost of anchor piers	$ 161,400
Total cost of bridge	$4.080,000

1,700-foot Span Suspension Bridge.

Nickel steel, 18,360,000 pounds at 8c	$1,468,800
Carbon steel, 19,160,000 pounds at 5.6c	1,073,000
Cables, 10,965,000 pounds at 12.5c	1,370,600
Cable details	184,000
Total cost of superstructure metal	$4,096,400

Main Piers.

Shafts and walls, 11,380 cubic yards at $15	$ 170,700
Caissons 21,400 cubic yards at $25	535,000
Total cost of main piers	$ 705,700

Anchorages.

Shafts, 27,640 cubic yards at $15	$ 414,600
Box cribs, 24,000 cubic yards at $20	480,000
Piles below bases, 206,400 lineal feet at $1.50	309,600
Total cost of anchorages	$1,204,200

Approaches.

Steel trestles, 1,063 lineal feet at $358	$ 380,500
Total cost of bridge	$6,387,000

2,400-foot Span Cantilever Bridge.

Nicel steel, 87,750,000 pounds at 8c	$7,020,000
Carbon steel, 30,857,000 pounds at 5.6c	1,729,000
Total cost of metal	$8,749,000

Main Piers.

Shafts and walls, 16,720 cubic yards at $15	$ 250,800
Caissons, 34,140 cubic yards at $25	853,500
Total cost of main piers	$1,104,300

Anchor Piers.

Shafts, 10,020 cubic yards at $15	$ 150,300
Box cribs, 6,260 cubic yards at $20	125,200
Piles below bases, 54,600 lineal feet at $1.50	81,900
Total cost of anchor piers	$ 357,400
Total cost of bridge	$10,211,000

2,400-foot Span Suspension Bridge.

Nickel steel, 34,320,000 pounds at 8c	$2,745,600
Carbon steel, 41,182,000 pounds at 5.6c	2,306,200
Cables, 24,260,000 at 12.5c	3,032,500
Cable details	200,000
Total cost of superstructure metal	$8,284,300

Main Piers.

Shafts and walls, 17,440 cubic yards at $15	$ 261,600
Caissons, 30,000 cubic yards at $25	750,000
Total cost of main piers	$1,011,600

Anchorages.

By proportion from previous design	$2,200,000

Approaches.

Steel trestles, 1,500 feet at $358	$ 537,000
Total cost of bridge	$12,033,000

2,700-foot Span Cantilever Bridge.

Nickel steel, 136,028,000 pounds at 8c	$10,882,200
Carbon steel, 45,826,000 pounds at 5.6c	2,566,300
Total cost of metal	$13,448,500

Main Piers.

Shafts and walls, 21,240 cubic yards at $15	$ 318,600
Caissons, 40,060 cubic yards at $25	1,001,500
Total cost of main piers	$1,320,100

Anchor Piers.

By proportion from previous design	$ 500,000
Total cost of bridge	$15,269,000

2,700-foot Span Suspension Bridge.

Nickel steel, 43,200,000 pounds at 8c	$3,456,000
Carbon steel, 54,080,000 pounds at 5.6c	3,028,500
Cables, 33,150,000 pounds at 12.5c	4,143,800
Cable details	250,000
Total cost of superstructure metal	$10,878,300

Main Piers.

Shafts and walls, 19,600 cubic yards at $15	$ 294,000
Caissons, 32,720 cubic yards at $25	817,500
Total cost of main piers	$1,111,500

Anchorages.

By proportion from previous design	$2,664,000

Approaches.

Steel trestles, 1,688 feet at $358	$ 604,300
Total cost of bridge	$15,258,000

COMBINED RAILWAY AND HIGHWAY BRIDGES.

1,500-foot Span Cantilever Bridge.

Nickel steel, 48,760,000 pounds at 8c	$3,900,800
Carbon steel, 42,027,000 pounds at 5.6c	2,353,500
Total cost of metal	$6,254,300

Main Piers.

Shafts and walls, 14,960 cubic yards at $15	$ 224,400
Caissons, 11,260 cubic yards at $25	281,500
Total cost of main piers	$505,900

Anchor Piers.

Concrete, 19,352 cubic yards at $15	$ 290,300
Total cost of bridge	$7,050,000

1,500-foot Span Suspension Bridge.

Nickel steel, 18,750,000 pounds at 8c	$1,500,000
Carbon steel, 38,780,000 pounds at 5.6c	2,171,700
Cables, 15,850,000 pounds at 12.5c	1,981,300
Cable details	277,000
Total cost of superstructure metal	$5,930,000

Main Piers.

Shafts and walls, 13,600 cubic yards at $15	$ 204,000
Caissons, 9,460 cubic yards at $25	236,500
Total cost of main piers	$ 440,500

Anchorages.

Concrete, 81,480, cubic yards at $15	$1,222,200

Approaches.

Steel trestles, 938 feet at $1,000	$ 938,000
Total cost of bridge	$8,531,000

HIGHWAY BRIDGES.

1,000-foot Span Cantilever Bridge of Carbon Steel.

Carbon steel metal, 19,338,000 pounds at 5.6c	$1,083,000

Main Piers.

Shafts and walls, 11,380 cubic yards at $15	$ 170,700
Caissons, 7,440 cubic yards at $25	186,000
Total cost of main piers	$ 356,700

Anchor Piers.

Concrete, 4,000 cubic yards at $15	$ 60,000
Total cost of bridge	$1,500,000

1,000-FOOT SPAN SUSPENSION BRIDGE OF CARBON STEEL.

Carbon steel, 8,662,000 pounds at 5.6c	$485,100
Cables, 2,223,000 pounds at 12.5c	277,900
Cable details	20,000
Total cost of superstructure metal	$783,000

Main Piers.

Shafts and walls, 9,092 cubic yards at $15	$136,400
Caissons, 5,000 cubic yards at $25	125,000
Total cost of main piers	$277,700

Anchor Piers.

By proportion from previous design	$280,000

Approaches.

Steel trestles, 625 feet at $300	$187,500
Total cost of bridge	$1,528,000

1,000-FOOT SPAN CANTILEVER BRIDGE OF NICKEL STEEL.

Nickel steel, 10,600,000 pounds at 8c	$848,000
Carbon steel, 2,500,000 pounds at 5.6c	140,000
Total cost of metal	$988,000

Main Piers.

Figured previously for another case	$330,000

Anchor Piers.

Concrete, 3,560 cubic yards at $15	$ 53,400
Total cost of bridge	$1,371,000

1,000-FOOT SPAN SUSPENSION BRIDGE OF NICKEL STEEL.

Nickel steel, 3,450,000 pounds at 8c	$276,000
Carbon steel, 2,650,000 pounds at 5.6c	148,400
Cables, 1,872,000 pounds at 12.5c	234,000
Cable Details	18,000
Total cost of superstructure metal	$676,000

Main Piers.

Shafts and walls, 7,840 cubic yards at $15	$117,600
Caissons, 5,000 cubic yards at $25	125,000
Total cost of main piers	$242,600

Anchor Piers.

By proportion from previous design	$260,000

Approaches.

Steel trestles, 625 feet at $300	$187,500
Total cost of bridge	$1,366,000

2,900-FOOT SPAN CANTILEVER BRIDGE.

Of High-Alloy Steel Having E. L. Equal to 80,000 Pounds Per Square Inch.

Alloy steel, 127,224,000 pounds at 9c	$11,450,000
Carbon steel, 44,462,000 pounds at 5.6c	2,490,000
Total cost of metal	$13,940,000

Main Piers.

Figured previously for another case	$1,320,000

Anchor Piers.

By proportion from a previous design	$ 460,000
Total cost of bridge	$15,720,000

2,900-FOOT SPAN SUSPENSION BRIDGE.

Of High-Alloy Steel Having E. L. Equal to 80,000 Pounds Per Square Inch.

Alloy Steel, 37,700,000 pounds at 9c	$3,393,000
Carbon steel, 54,758,000 pounds at 5.6c	3,066,000
Cables, 33,540,000 pounds at 12.5c	4,192,500
Cable details	260,000
Total cost of superstructure metal	$10,911,500

Main Piers.

Figured previously for another case	$1,112,000

Anchor Piers.

By proportion from a previous design	$2,560,000

Approaches.

Steel trestles, 1,813 feet at $358	$ 649,000
Total cost of bridge	$15,233,000

Economic Span Lengths for Simple-truss Bridges on Various Types of Foundation

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To be presented September 8, 1919.

UP to the present time the general knowledge possessed by the engineering profession concerning economic span lengths for bridges has been rather crude and unsatisfactory. Until three decades ago the only data available on this subject were covered by the broad statement that the greatest economy in a bridge layout exists when the cost of a span is equal to the cost of a pier. In his pamphlet on "General Specifications for Highway Bridges of Iron and Steel," issued in 1888, the author pointed out the fact that the then popular impression concerning this question was incorrect, because the cost of the floor is constant, and hence the adjustment is one between cost of substructure and cost of metal in trusses and laterals: Three years later he gave, in a paper published by "Indian Engineering," a mathematical demonstration of the theory of the economics of bridge layouts, showing that the greatest economy will exist when the cost of a pier is equal to one-half of that of the trusses and laterals of the two spans which it helps to support. This demonstration was based upon the assumptions that the piers rest on hard material and that, in most cases being of minimum size, they would not vary in dimensions or total cost for small changes in the span lengths.

This principle, though, is not applicable to the case of piers resting on sand or on piles, because the cost per lineal foot for substructure is often nearly constant for all moderate span lengths, while that for the superstructure augments; and this fact is not at all generally recognized by bridge designers. It has become evident of late to the author, by reason of some important bridge studies which he has been called upon to make in his practice, that there is needed by the profession a systematic investigation to determine in an authentic manner the economic span lengths for simple truss bridges to support the different kinds of live loads by piers resting on various types of foundation at all practicable depths, and to conform to changing market prices for materials in place.

In connection with the series of economic studies on bridge design which the author has been making, especially of late years, and which he hopes to complete before he passes on, this question had to be settled sooner or later, consequently he has just spent three weeks in computing the actual costs of both substructure and superstructure for over two hundred cases of bridge layouts covering the following combinations:

Railway, Highway, and Combined Railway and Highway Bridges on Concrete Pier Shafts overlying Caissons or Cribs rest-

ing on Sand, Bed-Rock, or Piles, and reaching to depths below low water of 50, 100, 150, 200, and 250 feet, also for low, medium, and high conditions of the material market.

The fact that all the computations were prepared by the author alone, and without a detailed check on the figuring, need not cause any doubt about the correctness of the results of his work, because all of them were plotted on cross section diagrams, and, consequently, whenever any error of the least importance was made it was detected at once.

This investigation owes its existence to the fact that recently the author, as a member of the board of advisory engineers to the Public Belt Railroad Commission of New Orleans (appointed to study the question of bridging or tunneling the Mississippi River at or near that city), had occasion to make a large number of layouts with cost estimates for railway, highway, and combined railway and highway bridges having sand foundations two hundred and fifty feet below the Gulf level. While the conditions precedent for those computations were used for certain of the layouts of this investigation, the actual results thereof were not incorporated, because all the calculations involved in this paper were special and had to be systematized. However, there were numerous deductions made from the New Orleans bridge studies, which permitted the adoption of valuable short cuts in figuring.

A large portion of the data employed in making estimates of cost was taken from the various diagrams given in the author's treatise, "Bridge Engineering," including live loads, impact, and weights of metal.

The following are the assumptions and conditions precedent adopted for the series of calculations:

CHARACTER OF STRUCTURES

The different classes of bridges covered are Double Track Railway, Single Track Railway, Standard Highway, and Combined Double Track Railway and Highway, all metal being carbon steel (excepting in one set of estimates where nickel steel was employed), the railway floors being open, the highway floors being paved with creosoted blocks resting on a reinforced concrete base, the footwalks being slabs of reinforced granitoid, and the handrails being of steel.

The highway bridges considered are all of the author's adopted standard type, viz., carbon steel trusses, laterals, and floor-system with a 42-foot paved roadway supported on a reinforced concrete base, two 8-foot sidewalks of reinforced granitoid carried on cantilever brackets, and two steel handrails, making the deck about sixty feet wide from out to out, exclusive of the space occupied by the trusses in through bridges.

All pier-shafts are of plain concrete with a coping, the batter being 1″ to 1′ for low-level railway and combined bridges, ¾″ to 1′ for high-level railway and combined bridges, and ½″ to 1′ for high-

way bridges, excepting in one set of estimates for low-level structures where a batter of 1″ to 1′ was employed.

All caissons founded on sand are of timber with concrete filling having steel bases and cutting edges; and they are made as light as is legitimate by omitting to fill a large proportion of the excavating shafts. But when the caissons reach bed-rock they are assumed to be filled solid. The depth of water in each case is taken as one-third of the vertical distance between extreme low water and caisson footing.

In the pile piers the piles are seventy-five feet long and project sixty feet below the bases, which are assumed to be twenty feet high, the piles being spaced three feet from centre to centre.

The character of the materials passed through during the sinking is assumed to be the ordinary mixture of silt, quicksand, soft gumbo, and other river deposits, overlying either coarse sand, suitable for foundations, or bed-rock.

METHODS OF PIER SINKING.

The methods assumed for sinking the caissons are those of open dredging and the pneumatic process, the former being employed when the bases are to rest on sand and the latter when they are to reach bed-rock. In the case of pile piers, the open box is first to be sunk by dredging to the required depth, then the piles are to be driven inside of it, and finally the remaining space is to be filled with concrete.

SPECIFICATIONS FOR DESIGNING.

The specifications for the designing of superstructure are those given in Chapter LXXVIII of the author's "Bridge Engineering," and those for the designing of substructure are to be found in Chapters XXXIX to XLIII, inclusive, of that treatise.

LOADS.

The live loads for superstructure for the several kinds of bridges are given on Fig. 1, and those for substructure on Fig. 2. The former include impact allowances, while the latter do not. Fig. 3 records the weights of metal per lineal foot of span in the superstructures of the various kinds of bridges considered. The live loads for highway and combined railway and highway bridges include the proper allowances for electric railway cars or trains.

The weights per lineal foot for the flooring are as given in the following table:

Character of structure—	Weight per lineal foot for flooring, exclusive of all steel but reinforcing bars
Low level combined bridges	5,800 pounds
High level combined bridges	6,900 pounds
Double track railway bridges	900 pounds
Single track railway bridges	450 pounds
Standard highway bridges	6,100 pounds

PERMISSIBLE PRESSURES ON SOIL AND PILES

For sand foundations the method of determining the permissible pressure beneath the base of the caisson is that evolved by the author in making his before mentioned computations for the New Orleans bridge study. It consists of allowing four tons per square foot plus the intensity of pressure on the adjacent soil at the elevation of the base, due to the *net* weight of the overlying solid material, after having deducted from the net weight of the caisson and its superimposed load for side friction at the rate of 400 pounds per square foot of lateral surface in contact with solid material. The net weight of the water soaked timber in the caisson is taken as zero and that of the concrete at eighty pounds per cubic foot. The partially filled caissons when complete weigh about fifty-six pounds *net* per cubic foot.

As a matter of precaution, the caissons have to be figured for side frictional resistance of 600 pounds per square foot during sinking, or sometimes (in extreme cases) 500 pounds per square foot. Of course, it is practicable to load temporarily the caisson as it reaches the neighborhood of its final position; but such an expedient is sometimes costly and troublesome, hence it is better to design it large enough to avoid the probability of holdup.

Some engineers have objected to relying upon side friction in supporting the load, but their contention is wrong, because it certainly does exist, and it has to be overcome before any settlement of the finished pier can occur. In the case of long piles driven into soft material, it is almost entirely the side friction which gives them supporting power. Again, someone may question the correctness of loading sand *apparently* as high as nine tons per square foot at a depth of 250 feet below low water level, when the depth of water is eighty feet; but it must be remembered that the *net* weight of 170 feet of earth loads the soil some five tons per square foot, and that before any settlement can occur, the material adjacent to the caisson has to be raised. The reason for this is that the sand at such a great depth is practically incompressible and that for any settlement to occur it must flow. It cannot flow downward or laterally, because there is no vacant space for it to fill; consequently, if flow it must, it will have to pass upward; and in order to do so it must lift a large column of the adjacent solid material. In the author's opinion, it would take an excessively large unit loading on the base of a filled caisson resting on coarse sand at a depth of two hundred and fifty feet to cause the slightest settlement.

The permissible loading for long piles has been taken at forty tons per pile, this being in accordance with the author's practice for a quarter of a century; and he has never yet found any settlement to occur under such loading.

UNIT PRICES OF MATERIALS IN PLACE.

The following table gives the unit prices for materials in place assumed for the purpose of this investigation:

Materials.	Condition of Market. Low.	Medium.	High.
Structural steel, per pound..........	4c	6c	8c
Concrete shafts of 20′ average thickness, per cubic yard.............	$ 9.00	$12.00	$15.00
Mass of caissons, including all materials, for a width of 30′ and a height of 150′, sunk by open-dredging, per cubic yard	15.00	20.00	25.00
Mass of cribs, including enclosed pile-heads, per cubic yard............	15.00	20.00	25.00
Portion of long piles projecting below base of crib, per lineal foot.......	.75	1.00	1.25

For the "Medium Condition of Market," the price per cubic yard of the shafts is to be modified by the addition or subtraction of fifteen cents for each foot of variation from the assumed average of twenty, the greater the thickness the smaller the unit price. For instance, if a shaft were 12 feet wide under coping and 18 feet wide at the bottom, the average width would be 15 feet and the unit price for medium market $12.75.

For the same market condition the unit price for mass of caissons is to be modified by the addition or subtraction of ten cents for each foot of variation from the assumed average of thirty, the wider the caisson the smaller the price per cubic yard. Again, for the said market condition, the unit price for mass of caissons is to be modified by the addition or subtraction of two cents for each foot of variation from the assumed average height of one hundred and fifty feet, the deeper the caisson the smaller the unit price. For instance, with medium condition of market, the unit price for a caisson twenty-six feet wide and two hundred and forty feet high would be

$$20.00 + 4 \times 0.10 - 90 \times 0.02 = \$18.60.$$

For the other two assumed conditions of the market, these figures of modification would have to be multiplied by the ratios indicated in the table, viz., 0.75 and 1.25.

Without these modifications of unit prices for substructure, the investigation would be not only illogical, but incorrect. The variation in cost of shafts per cubic yard is due primarily to the lower unit cost of forms for thick piers, but also somewhat to the economy effected by manufacturing and handling larger masses of concrete. The latter reason applies also to the two variations in the cost of

mass of caissons; but the main cause thereof is that the total cost of cutting edge, shelter against current, and flotation to final location are the same for a shallow base as for a deep one.

The prices per cubic yard for caissons sunk by the pneumatic process under medium market conditions, have been made two dollars greater than those for caissons sunk by open-dredging. This is in conformity with the author's bridge experience of nearly four decades. It is due primarily to the more rapid sinking by open dredging, but also to the fact that the pneumatic caissons are generally filled solid, while the open dredging caissons often have their excavating wells only partially filled.

The price used for nickel steel superstructure in place for Medium Market conditions has been taken as eight and a half cents per pound; for the reason that the last ante-bellum figures on structures, designed partially with that alloy, quoted to the author made the price of the nickel steel portion two and a half cents per pound higher than that of the carbon-steel portion. The weights of metal in nickel-steel superstructures were computed by means of ratios determined from diagrams given in the author's paper "Nickel Steel for Bridges."*

METHOD OF DETERMINING THE ECONOMIC SPAN LENGTHS.

In determining the economic span lengths, computations were made for the volumes of concrete in shafts, volumes of caissons, volumes of cribs, total lengths of piles below crib bases, and weights of metal in spans, but no notice was taken of the cost of flooring, as that is a constant for any type of bridge. In order, however, that the diagrams of this paper may be used for future bridge estimates, there is included herein a table giving the costs of flooring per lineal foot of span for all the classes of bridges investigated and for the three before mentioned conditions of the material market.

It might be well to mention that while the abscissae of the diagrams give the span lengths measured from center to center of end pins, the costs of structure per lineal foot were computed by using the distance from center to center of piers.

In making each of these cost estimates there was assumed a structure of indefinitely great length and unvarying profile, so that the sum of the cost of the steel work in a span and the cost of a complete pier divided by the horizontal distance between adjacent pier centers gives the comparing cost per lineal foot of structure, although, as before indicated, not the *complete* cost thereof.

The results of all calculations made were plotted on cross-section diagrams, but only those thereof which are truly necessary for explanation or useful for reference in estimating costs of bridges

*See Trans. Am. Soc. Civ. Engrs. for 1909.

have been reproduced herein. However, the important deductions from all the estimates have been tabulated. The plotting was done with the utmost care, and due consideration was given to a proper determination of the economic span length. As previously indicated, a number of arithmetical errors were located and corrected by reason of irregularities in the curves, thus making the latter truly reliable. In almost all cases, at least four points were plotted from computations, in order to locate the curves of cost for substructure and for the steelwork of superstructure; and a combination of these was used for locating a few intermediate points on the curve which gives the combined cost of substructure and steelwork. In a few instances, though, three points for the lower curves were found to be sufficient for a correct plotting of the upper curve.

COSTS OF FLOORING.

The costs of flooring per lineal foot of span, previously referred to, are as given in the following table. They cover rails, with their fastenings, guard-rails, and ties for both steam and electric railway tracks; pavements and their supporting slabs, with the reinforcing bars, for roadways; and concrete or granitoid footwalk slabs, with the reinforcing bars, all complete in place.

Cost Per Lineal Foot of Span for Flooring.

Type of Structure.	Condition of Market. Low.	Medium.	High.
Low level, double-deck, combined	$27.00	$36.00	$45.00
High level, single-deck, combined	31.50	42.00	52.50
Double track, steam railway	9.00	12.00	15.00
Single track, steam railway	4.50	6.00	7.50
Standard highway, 60 feet wide out to out	25.50	34.00	42.50

RECORDING DIAGRAMS AND TABLE.

On Figs. 4 to 36, inclusive, are graphically recorded the most important of the results of the special calculations. Each diagram contains three curves, one for substructure, one for steelwork in superstructure, and the other for a combination of these two. The computed cost points therefor are marked on the three curves, respectively, by circles, squares and diamonds. The abscissae of these diagrams give the span lengths in feet, measuring from center to center of bearings; and the ordinates record the cost per lineal foot, measuring from center to center of piers. On each diagram is clearly indicated the span length for greatest economy; and it is to be noticed by the flatness of the upper curves that a variation of twenty-five feet or more, either above or below the economic length, will make very little difference in the cost per foot of structure. Each diagram is provided with a title which indicates clearly the type of structure and depth of foundation to which

it refers. Unless otherwise shown thereon, these diagrams relate to normal or medium conditions of the material market.

In the following table is given a résumé of the results of nearly all the cost computations that were prepared:

Résumé of Results of Computations.

No. of Fig.	Character of Structure.	Character of Foundations.	Depth of Caisson Footings.	Economic Span Lengths.	Remarks.
4.	Low-Level Combined	Sand	100′	275′	
5.	Low-Level Combined	Sand	150′	300′	Shaft Batter
6.	Low-Level Combined	Sand	200′	325′	1″ to 1′
7.	Low-Level Combined	Sand	250′	350′	
8.	Low-Level D. T. R. R.	Sand	100′	275′	
9.	Low-Level D. T. R. R.	Sand	150′	310′	Shaft Batter
10.	Low-Level D. T. R. R.	Sand	200′	360′	1″ to 1′
11.	Low-Level D. T. R. R.	Sand	250′	430′	
12.	High-Level Combined	Sand	100′	275′	
13.	High-Level Combined	Sand	150′	300′	Shaft Batter
14.	High-Level Combined	Sand	200′	325′	¾″ to 1′
15.	High-Level Combined	Sand	250′	350′	
16.	Low-Level Combined	Rock	50′	250′	Pneumatic
17.	Low-Level Combined	Rock	100′	300′	Caissons
18.	Low-Level D. T. R. R.	Rock	50′	275′	Pneumatic
19.	Low-Level D. T. R. R.	Rock	100′	325′	Caissons
20.	High-Level Combined	Rock	50′	300′	Pneumatic
21.	High-Level Combined	Rock	100′	350′	Caissons
22.	Low Level S. T. R. R.	Rock	50′	250′	Pneumatic
23.	Low Level S. T. R. R.	Rock	100′	300′	Caissons
24.	High-Level Combined	Piles	20′	175′	Pile Piers
25.	Low-Level Highway	Sand	100′	300′	
26.	Low-Level Highway	Sand	150′	350′	Shaft Batter
27.	Low-Level Highway	Sand	200′	400′	½″ to 1′
28.	Low-Level Highway	Sand	250′	450′	
29.	High-Level Highway	Sand	100′	325′	
30.	High-Level Highway	Sand	150′	350′	Shaft Batter
31.	High-Level Highway	Sand	200′	375′	½″ to 1′
32.	High-Level Highway	Sand	250′	400′	
33.	Low-Level D. T. R. R.	Sand	100′	350′	
34.	Low-Level D. T. R. R.	Sand	150′	385′	Nickel-Steel
35.	Low-Level D. T. R. R	Sand	200′	425′	Super-
36.	Low-Level D. T. R. R.	Sand	250′	470′	Structure
	Low-Level Highway	Sand	100′	275′	
	Low-Level Highway	Sand	150′	350′	Shaft Batter
	Low-Level Highway	Sand	200′	425′	1″ to 1′
	Low-Level Highway	Sand	250′	500′	
	Low-Level D. T. R. R.	Sand	100′	290′	
	Low-Level D. T. R. R.	Sand	150′	330′	Low-Market
	Low-Level D. T. R. R.	Sand	200′	375′	Unit-Prices
	Low-Level D. T. R. R.	Sand	250′	425′	
	Low-Level D. T. R. R.	Sand	100′	275′	
	Low-Level D. T. R. R.	Sand	150′	325′	High-Market
	Low-Level D. T. R. R.	Sand	200′	375′	Unit-Prices
	Low-Level D. T. R. R.	Sand	250′	425′	

From a study of the preceding table there can be drawn the following deductions:

A. For all types of bridges the economic span length increases with the depth of foundation, though not necessarily in the same proportion.

B. The lighter the superstructure and the live load it carries, the greater generally is the economic span length, and the greater the variation of the latter with the depth of foundation.

C. For sand foundations there is not much difference in the economic span lengths for low level and high level bridges of the same type.

D. Structures with piers founded on bed rock generally have economic span lengths somewhat greater than those of the corresponding structures founded upon sand.

E. Single track railroad bridges have economic span lengths a little less than those of the corresponding double-track structures.

F. Pile piers for high-level bridges involve, for economic considerations, rather short spans; and for low-level structures they usually necessitate such short ones as to require the adoption of plate girder superstructures.

G. In highway bridges having very deep foundations on sand, increasing the batter of the shaft augments the economic span length.

H. Using nickel steel instead of carbon steel in the superstructure increases materially the economic span length.

I. The assumed variations in unit prices with changing market conditions make very little difference in the economic span lengths. There would have been no difference at all had the prices of all the materials used been assumed to vary in the same proportion; but the superstructure steel, erected, ordinarily changes in value somewhat more rapidly than does the substructure of the bridge.

J. There are not many irregularities to be found in comparing the diagrams or the tabulated results of the calculations; and what few exist are small. They are generally due to the adoption of a minimum weight limit for sinking to great depths instead of figuring upon employing temporary loading, as shown, for instance, by the substructure curve of Fig. 15.

Certain of the cost curves in the preceding diagrams, in combination with other diagrams giving weights of steel distributed between trusses, laterals and floor systems, will provide a check on the correctness of these old methods of determining economic span lengths. Let us take the case of a low level, double track railway bridge founded on rock, find the cost per lineal foot of the trusses and laterals in the span of economic length, and check it against the cost per lineal foot for the substructure thereof. For a 50-foot depth of bed rock the economic span length is 275 feet;

and for that span (See "Birdge Engineering," pages 1239 and 1240) the weight of metal per lineal foot for trusses and laterals with Class 60 live load is 4,600 pounds, which at six cents per pound would be worth $276, while the cost per foot for the substructure given in Fig. 18 is $270. This is not a bad check.

For a depth of 100 feet, the economic span length is 325 feet, for which the weight of trusses and laterals is 5,860 pounds, which at six cents per pound would be worth $352. Fig. 19 makes the cost per foot for the substructure $420—quite a discrepancy.

For low level, single track railroad bridges with a foundation depth of 50 feet, the economic span length given in Fig. 22 is 250 feet, for which the weight of trusses and laterals is 2,480 pounds, which at six cents per pound would be worth $149, while the diagram gives the cost per foot for substructure at $175—not a close check.

For a depth of 100 feet, the economic span length is 300 feet, for which the weight of trusses and laterals is 3,050 pounds, which at six cents per pound would be worth $183. Fig. 23 makes the cost per foot for substructure $275—another large variation.

It is evident from the preceding comparisons of cost that the former rule for determining the economic span length is not reliable, especially for foundations at great depths; hence its use should be discontinued.

The contents of this paper are respectfully submitted to the bridge experts of America for comment and criticism; and the author hopes that the subject will not be overlooked by them, because a thorough discussion will settle all differences of opinion upon this exceedingly important point of engineering practice.

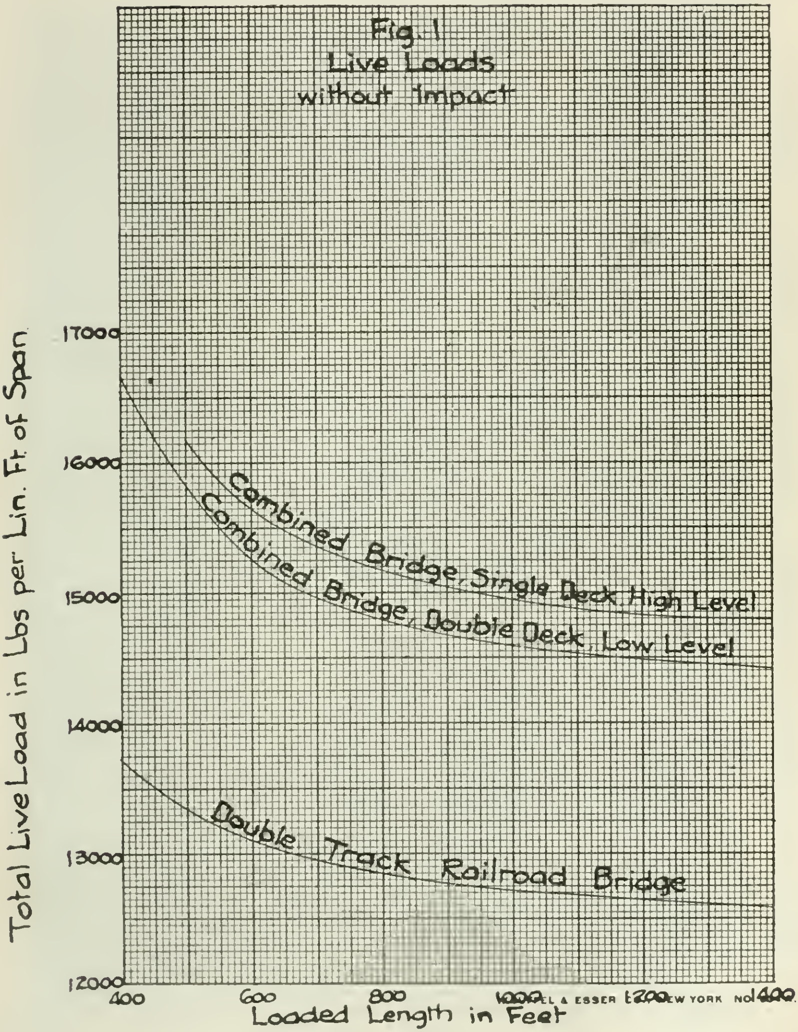


Fig. 1
Live Loads
without Impact
Total Live Load in Lbs per Lin. Ft. of Span
17000
16000
15000
14000
13000
12000
400
600
800
1000
1200
1400
Loaded Length in Feet
Combined Bridge, Single Deck High Level
Combined Bridge, Double Deck, Low Level
Double Track Railroad Bridge

Fig. 1

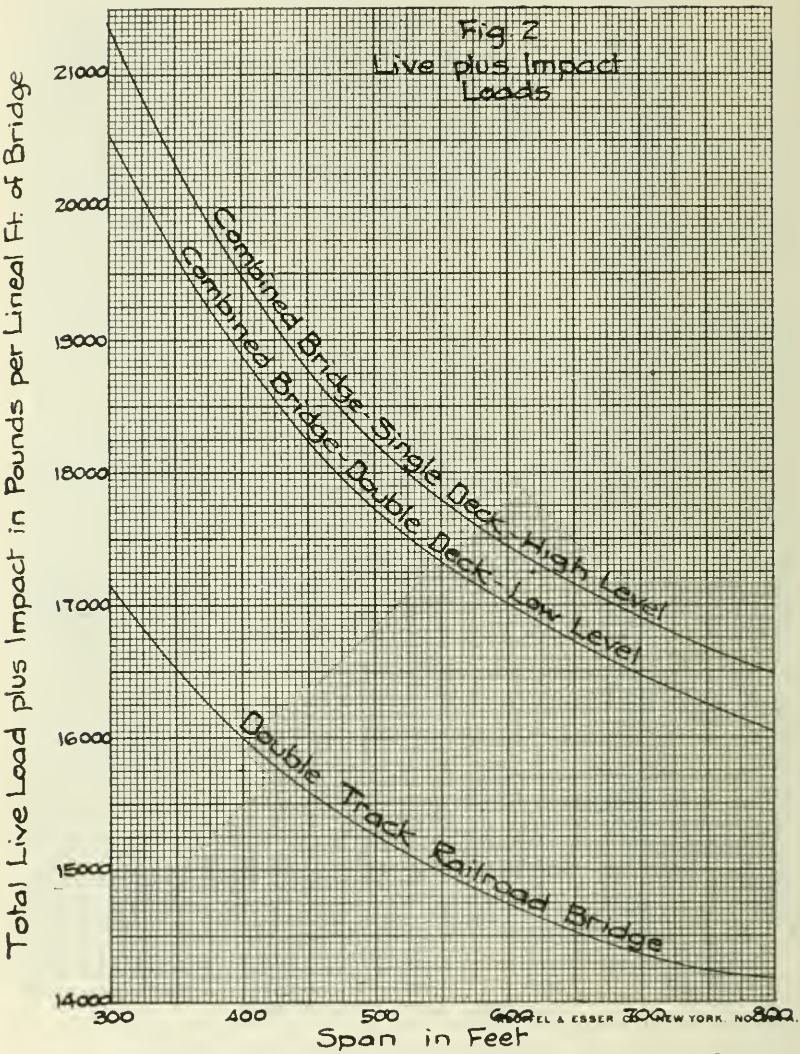


Fig. 2
Live plus Impact
Loads
Total Live Load plus Impact in Pounds per Lineal Ft. of Bridge
21000
20000
19000
18000
17000
16000
15000
14000
Combined Bridge-Single Deck-High Level
Combined Bridge-Double Deck-Low Level
Double Track Railroad Bridge
300
400
500
600
700
800
Span in Feet

Fig. 2

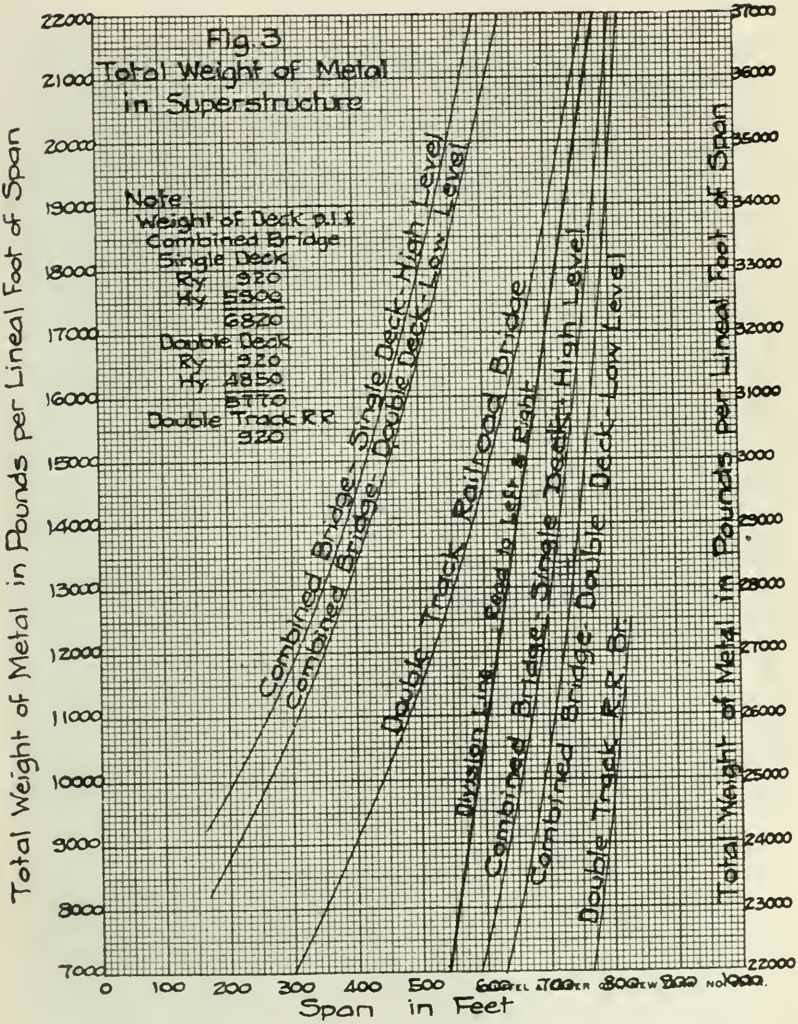


Fig. 3
Total Weight of Metal in Superstructure
Note:
Weight of Deck p.l.f.
Combined Bridge
Single Deck
Ry 920
Hy 5900
6820
Double Deck
Ry 920
Hy 4850
5770
Double Track R.R.
920
Combined Bridge - Single Deck - High Level
Combined Bridge - Double Deck - Low Level
Double Track Railroad Bridge
Division Line (Read to Left & Right)
Combined Bridge - Single Deck - High Level
Combined Bridge Double Deck - Low Level
Double Track R.R. Br.
Total Weight of Metal in Pounds per Lineal Foot of Span
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
Total Weight of Metal in Pounds Per Lineal Foot of Span
37000
36000
35000
34000
33000
32000
31000
30000
29000
28000
27000
26000
25000
24000
23000
22000
0 100 200 300 400 500 600 700 800 900 1000
Span in Feet

Fig. 3

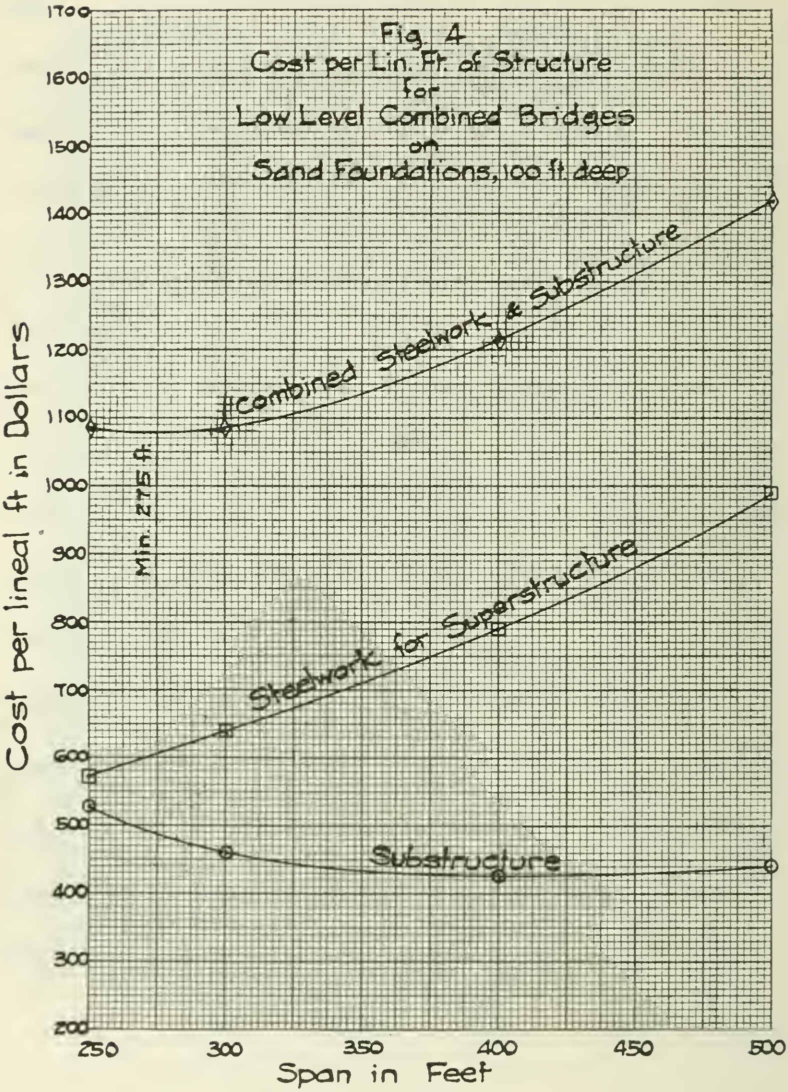


Fig. 4
Cost per Lin. Ft. of Structure
for
Low Level Combined Bridges
on
Sand Foundations, 100 ft. deep
Combined Steelwork & Substructure
Steelwork for Superstructure
Substructure
Min. 275 ft.
Cost per lineal ft in Dollars
Span in Feet
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
250
300
350
400
450
500

Fig. 4

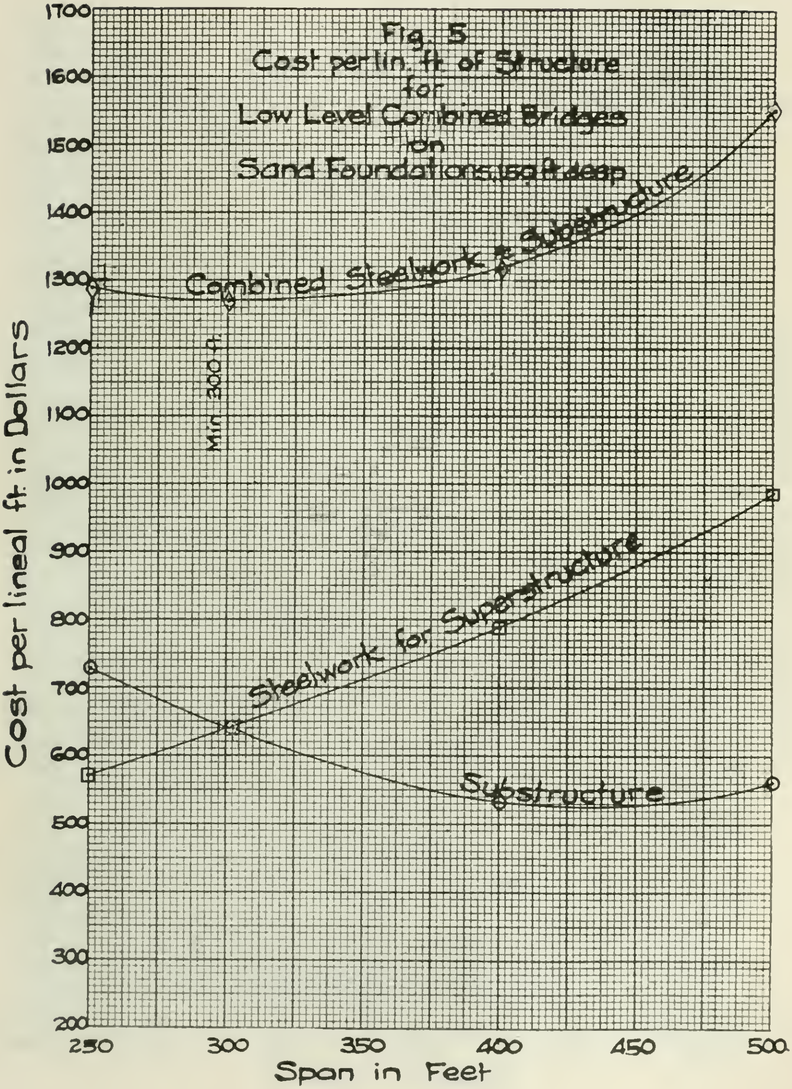


Fig. 5
Cost per lin. ft. of Structure
for
Low Level Combined Bridges
on
Sand Foundations 150 ft. deep
Combined Steelwork & Substructure
Min. 300 ft.
Steelwork for Superstructure
Substructure
Cost per lineal ft. in Dollars
Span in Feet
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
250
300
350
400
450
500

Fig. 5

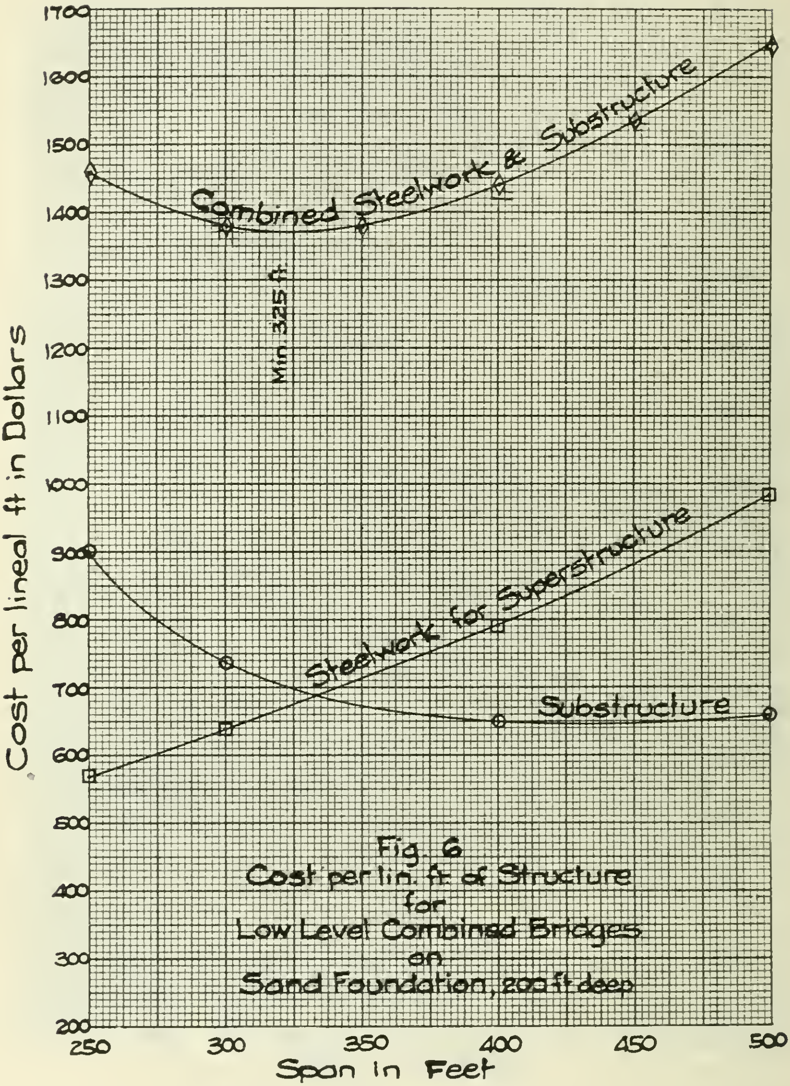

Combined Steelwork & Substructure
Min. 325 ft.
Steelwork for Superstructure
Substructure
Fig. 6
Cost per lin. ft. of Structure
for
Low Level Combined Bridges
on
Sand Foundation, 200 ft deep
Cost per lineal ft in Dollars
Span in Feet
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
250
300
350
400
450
500

Fig. 6

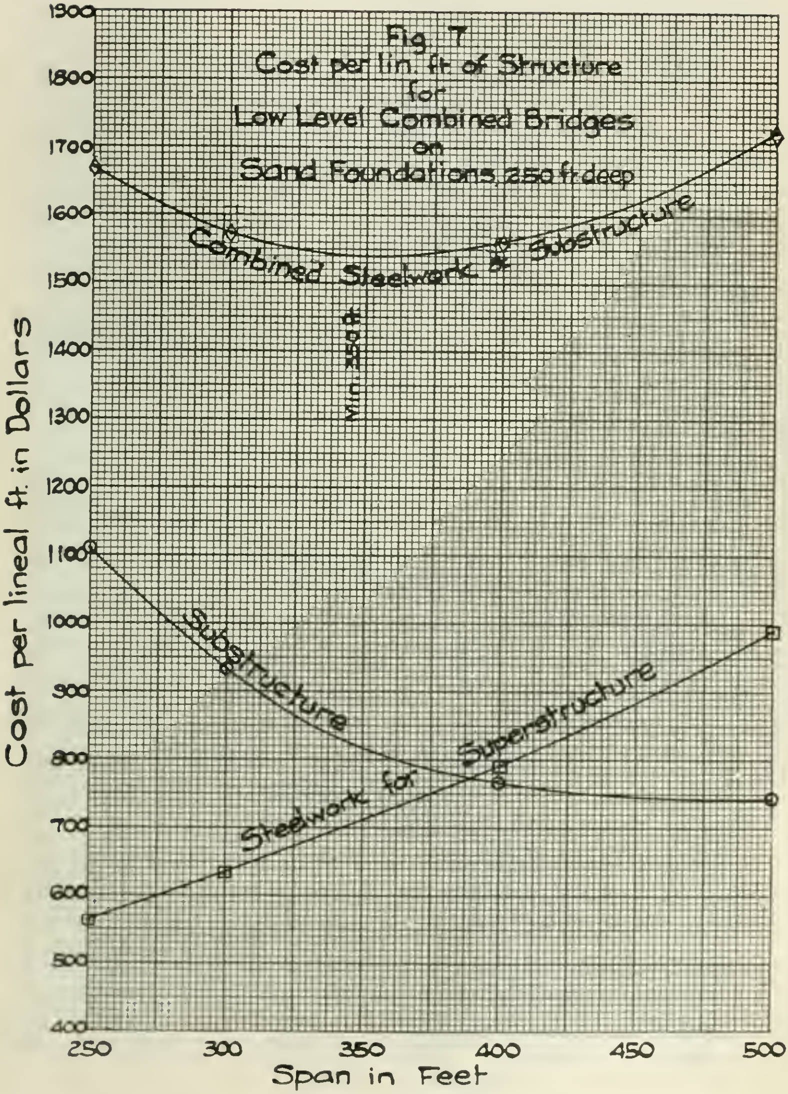


Fig. 7
Cost per lin. ft. of Structure
for
Low Level Combined Bridges
on
Sand Foundations 250 ft. deep
Combined Steelwork & Substructure
Min. 350 ft.
Substructure
Steelwork for Superstructure
Cost per lineal ft. in Dollars
Span in Feet
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
250
300
350
400
450
500

Fig. 7

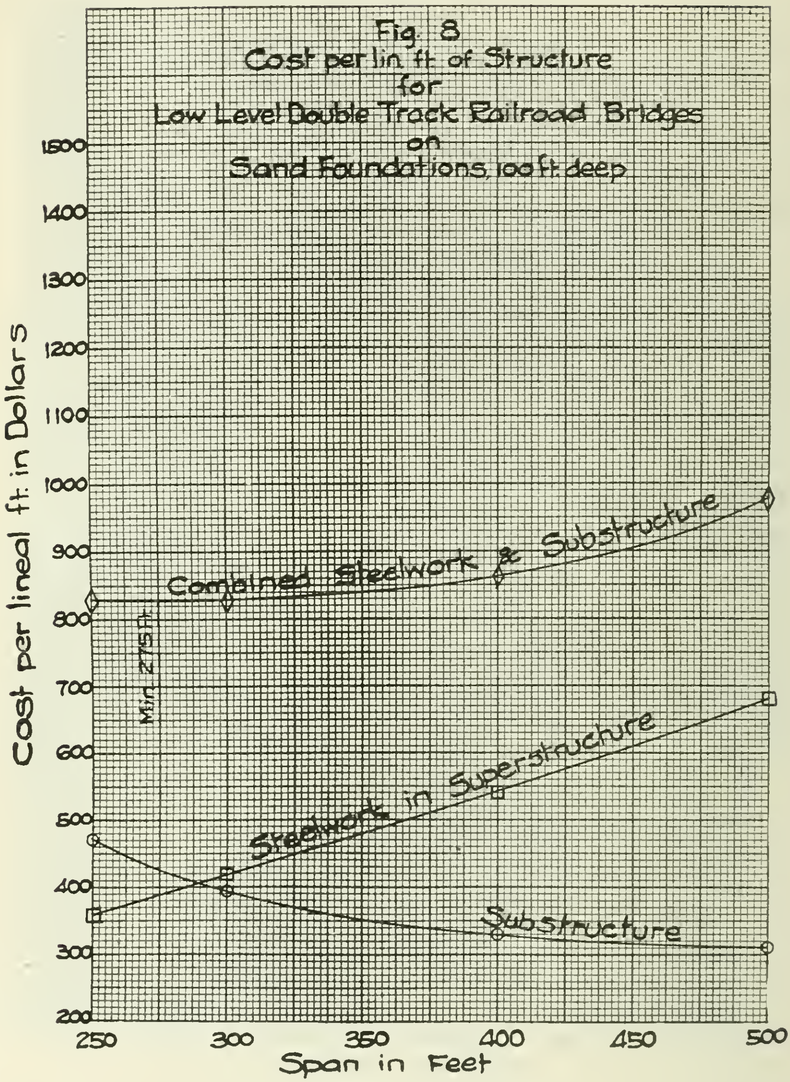


Fig. 8
Cost per lin. ft. of Structure
for
Low Level Double Track Railroad Bridges
on
Sand Foundations, 100 ft. deep
Cost per lineal ft. in Dollars
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
250
300
350
400
450
500
Span in Feet
Combined Steelwork & Substructure
Steelwork in Superstructure
Substructure
Min. 275 ft.

Fig. 8

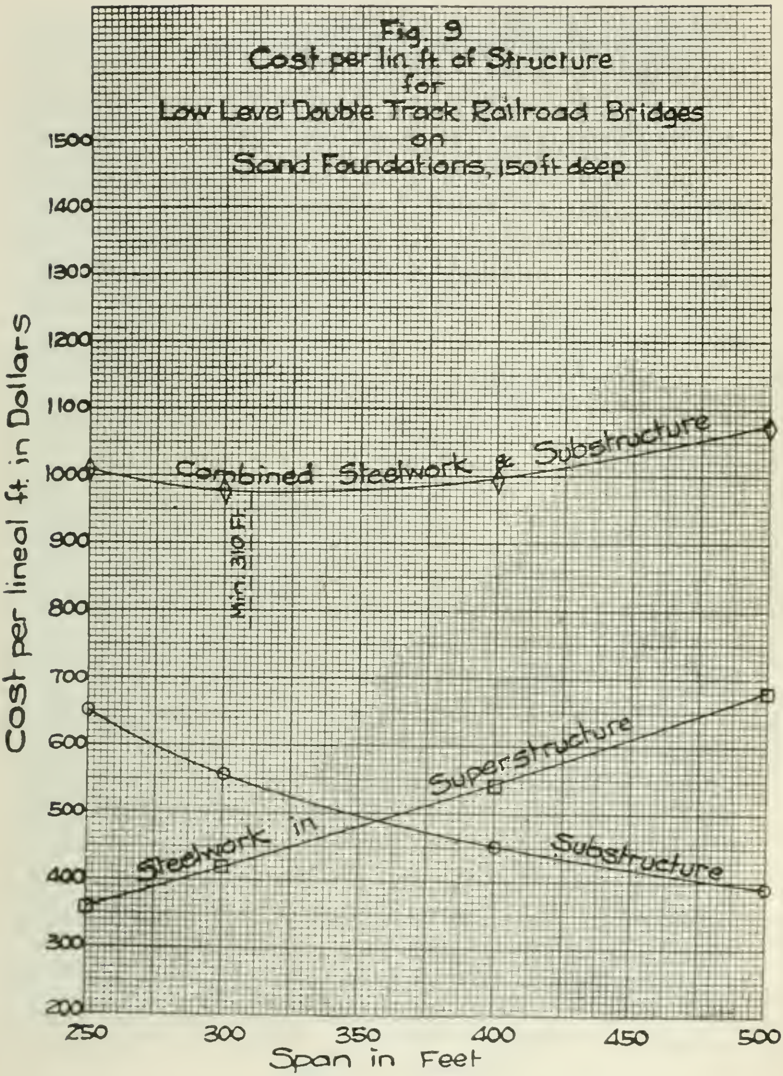


Fig. 9
Cost per lin. ft. of Structure
for
Low Level Double Track Railroad Bridges
on
Sand Foundations, 150 ft deep
Cost per lineal ft. in Dollars
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
Combined Steelwork & Substructure
Min. 310 Ft.
Steelwork in Superstructure
Substructure
250
300
350
400
450
500
Span in Feet

Fig. 9

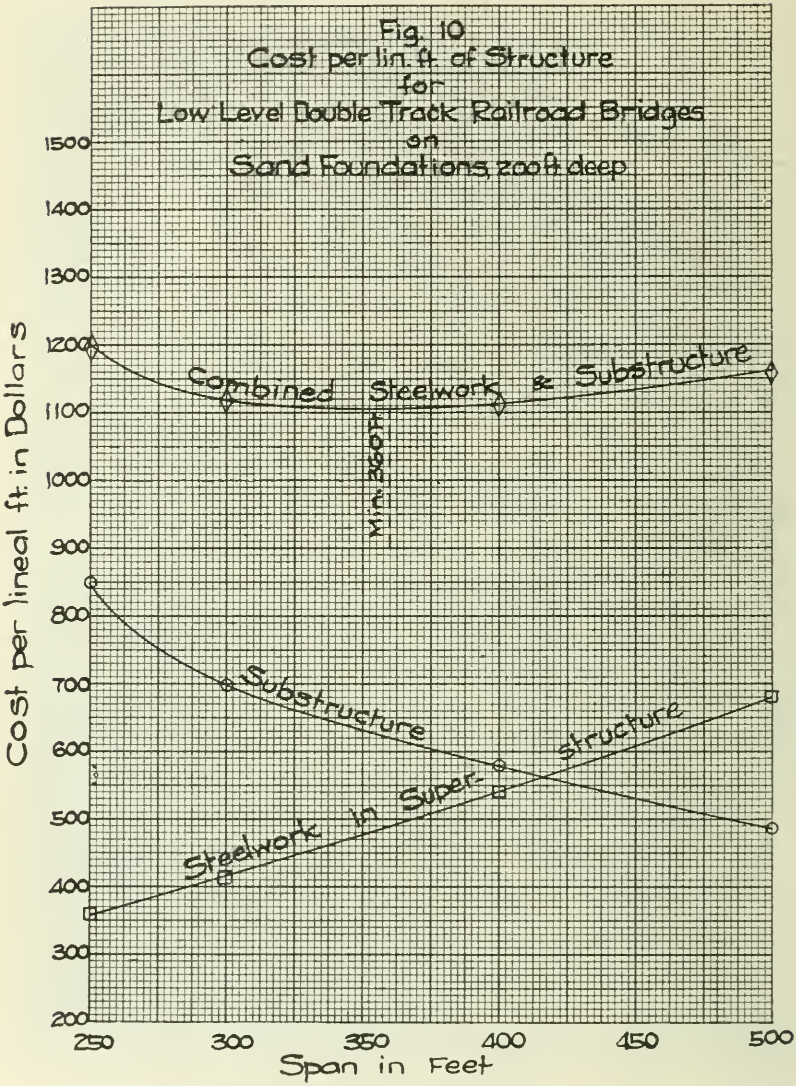


Fig. 10
Cost per lin. ft. of Structure
for
Low Level Double Track Railroad Bridges
on
Sand Foundations, 200 ft. deep
Cost per lineal ft. in Dollars
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
250
300
350
400
450
500
Span in Feet
Combined Steelwork & Substructure
Min. 360 ft.
Substructure
Steelwork in Super-structure

Fig. 10

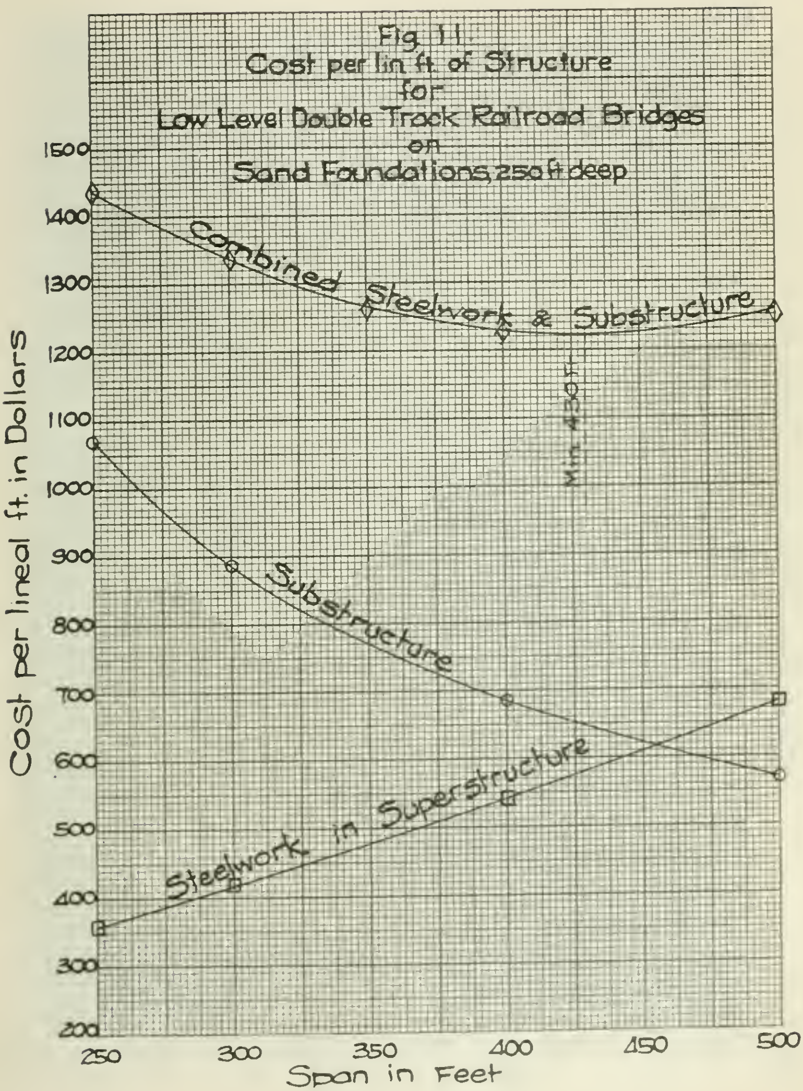


Fig. 11
Cost per lin. ft. of Structure
for
Low Level Double Track Railroad Bridges
on
Sand Foundations, 250 ft deep
Combined Steelwork & Substructure
Substructure
Steelwork in Superstructure
Min. 430 ft
Cost per lineal ft. in Dollars
Span in Feet
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
250
300
350
400
450
500

Fig. 11

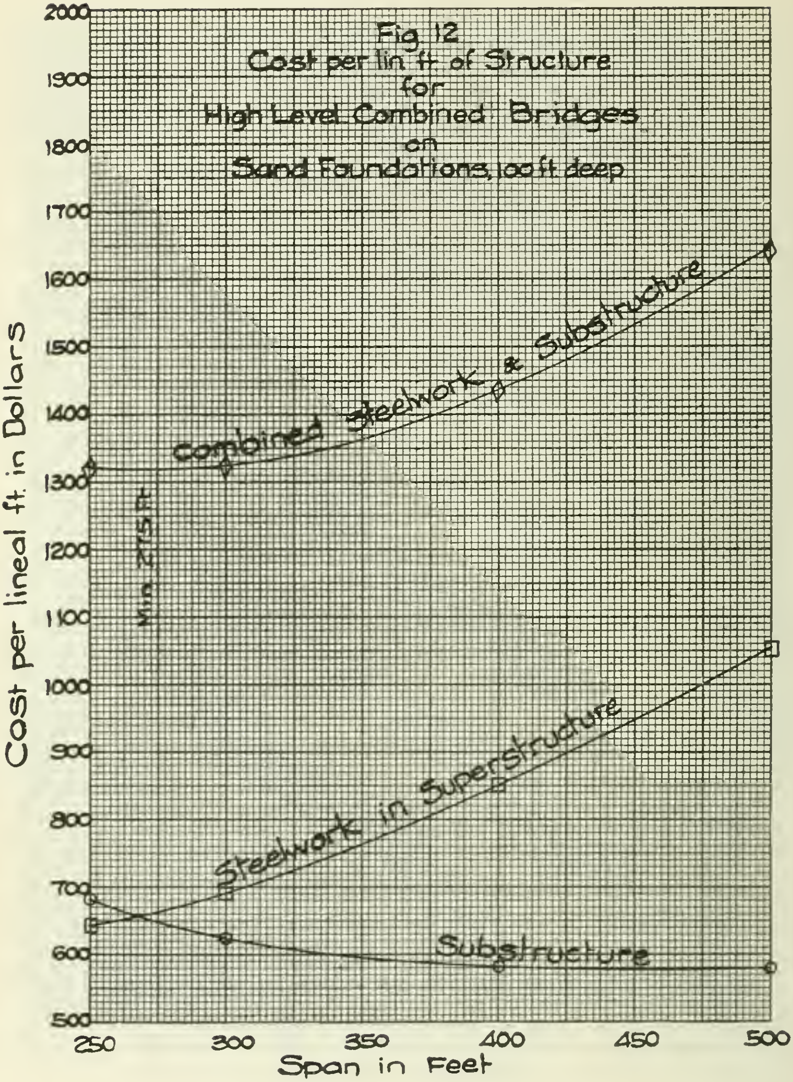


Fig. 12
Cost per lin ft of Structure
for
High Level Combined Bridges
on
Sand Foundations, 100 ft deep
Cost per lineal ft. in Dollars
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
Combined Steelwork & Substructure
Min 275 ft
Steelwork in Superstructure
Substructure
250
300
350
400
450
500
Span in Feet

Fig. 12

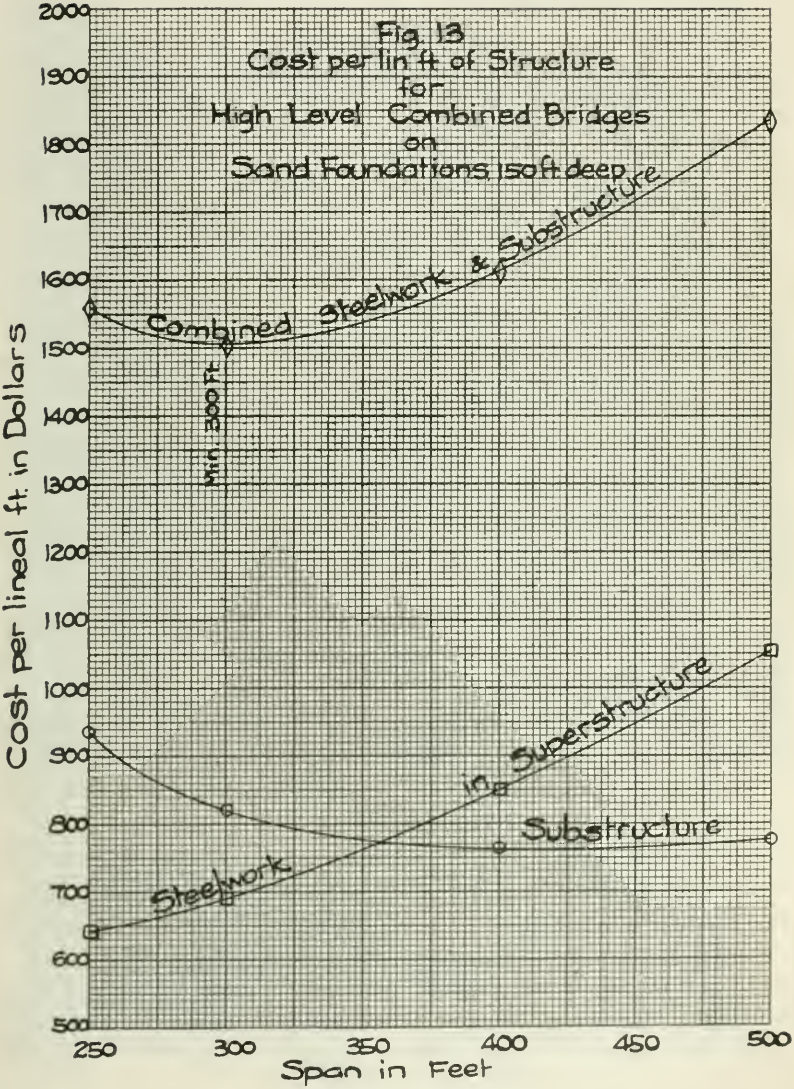


Fig. 13
Cost per lin ft of Structure
for
High Level Combined Bridges
on
Sand Foundations 150 ft deep
Combined Steelwork & Substructure
Min. 300 ft
Steelwork in Superstructure
Substructure
Cost per lineal ft. in Dollars
Span in Feet
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
250
300
350
400
450
500

Fig. 13

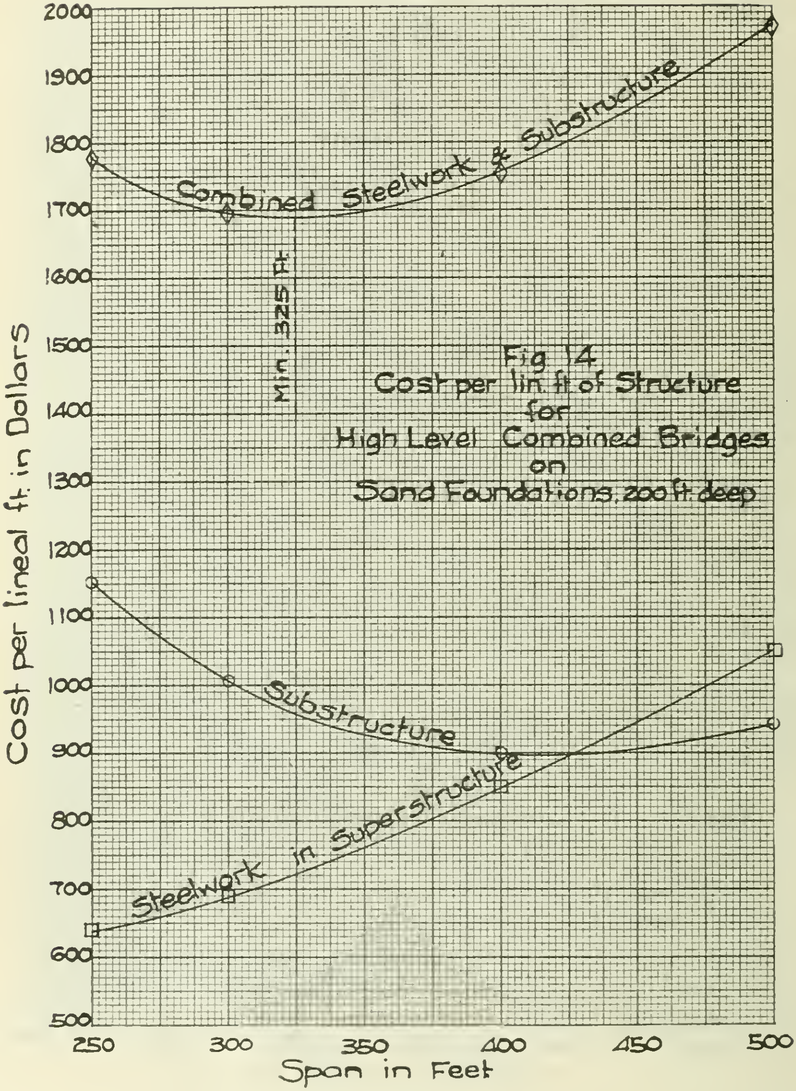


Fig 14
Cost per lin. ft of Structure
for
High Level Combined Bridges
on
Sand Foundations, 200 ft. deep
Combined Steelwork & Substructure
Min. 325 Ft.
Substructure
Steelwork in Superstructure
Cost per lineal ft. in Dollars
Span in Feet
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
250
300
350
400
450
500

Fig. 14

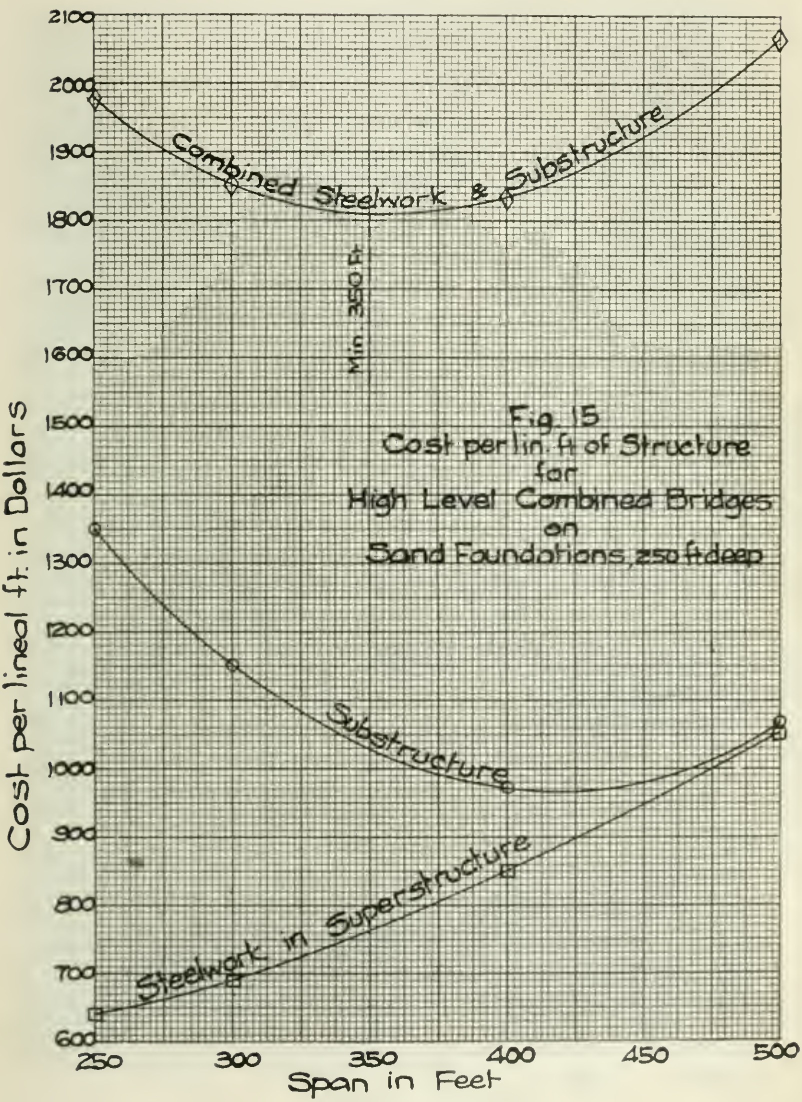

2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
Cost per lineal ft. in Dollars
250
300
350
400
450
500
Span in Feet
Combined Steelwork & Substructure
Min. 350 Ft.
Fig. 15
Cost per lin. ft. of Structure
for
High Level Combined Bridges
on
Sand Foundations, 250 ft. deep
Substructure
Steelwork in Superstructure

Fig. 15

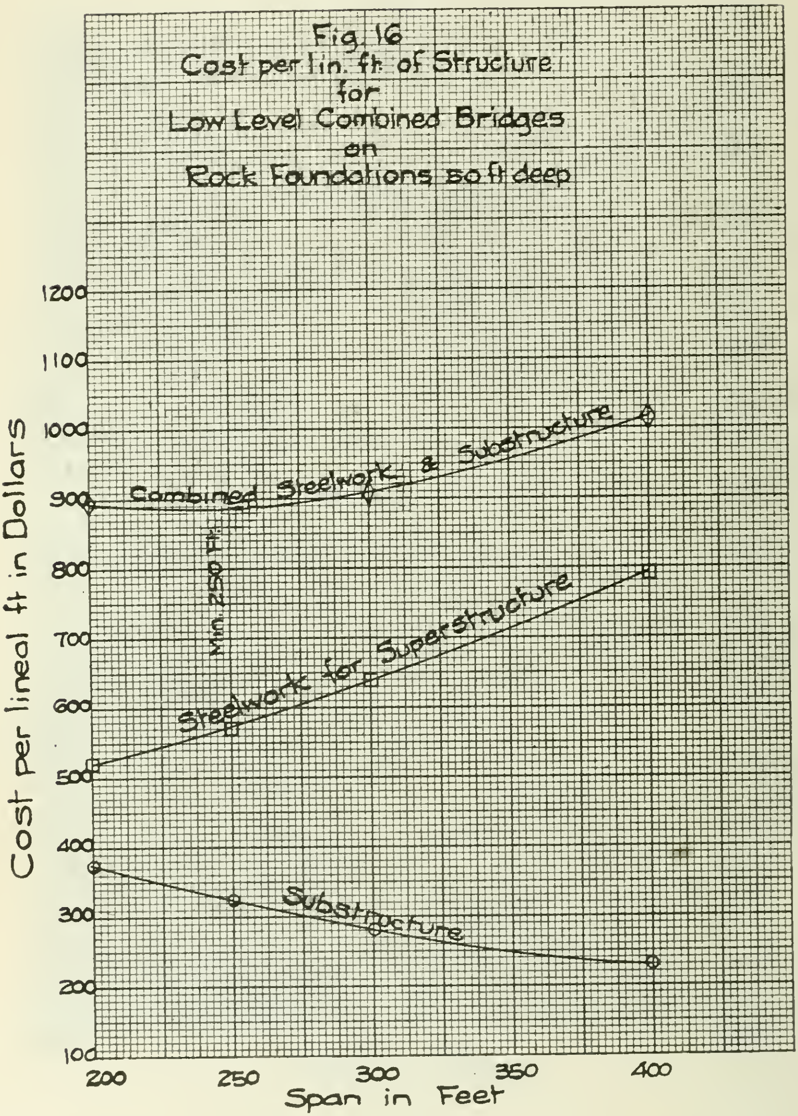


Fig. 16
Cost per lin. ft. of Structure
for
Low Level Combined Bridges
on
Rock Foundations 50 ft deep
Combined Steelwork & Substructure
Min. 250 Ft.
Steelwork for Superstructure
Substructure
Cost per lineal ft in Dollars
100
200
300
400
500
600
700
800
900
1000
1100
1200
200
250
300
350
400
Span in Feet

Fig. 16

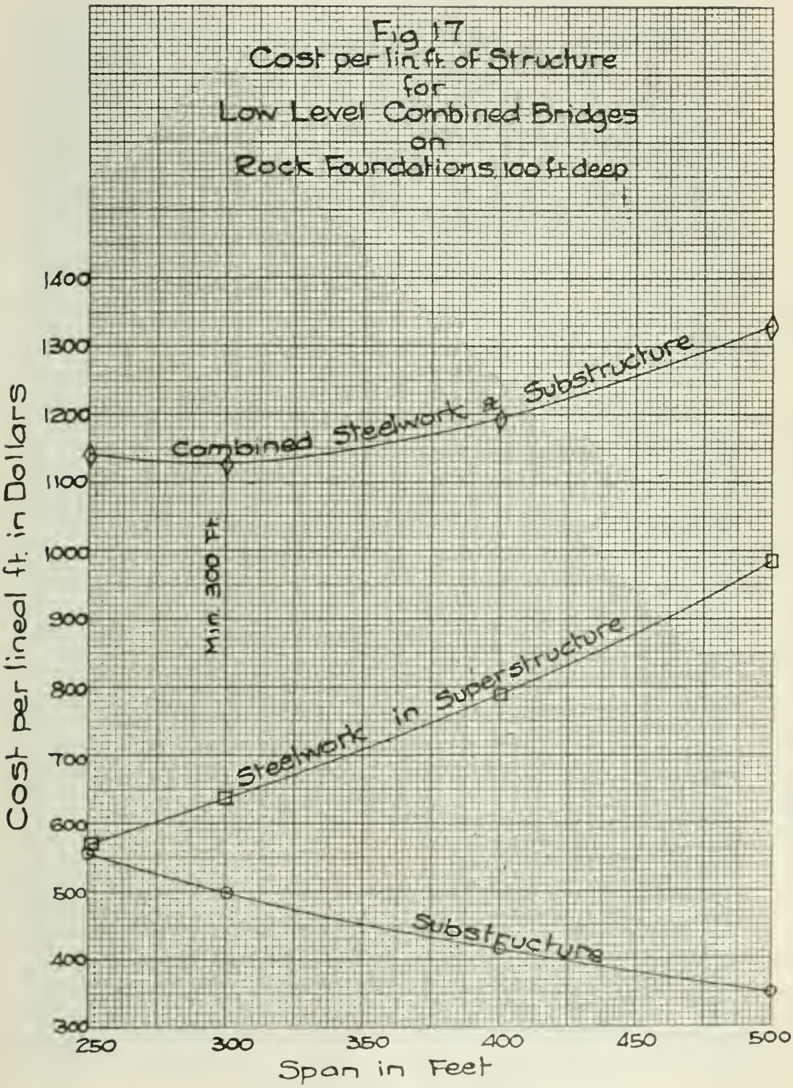


Fig 17
Cost per lin. ft. of Structure
for
Low Level Combined Bridges
on
Rock Foundations, 100 ft deep
Combined Steelwork & Substructure
Min. 300 Ft.
Steelwork in Superstructure
Substructure
Cost per lineal ft. in Dollars
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
250
300
350
400
450
500
Span in Feet

Fig. 17

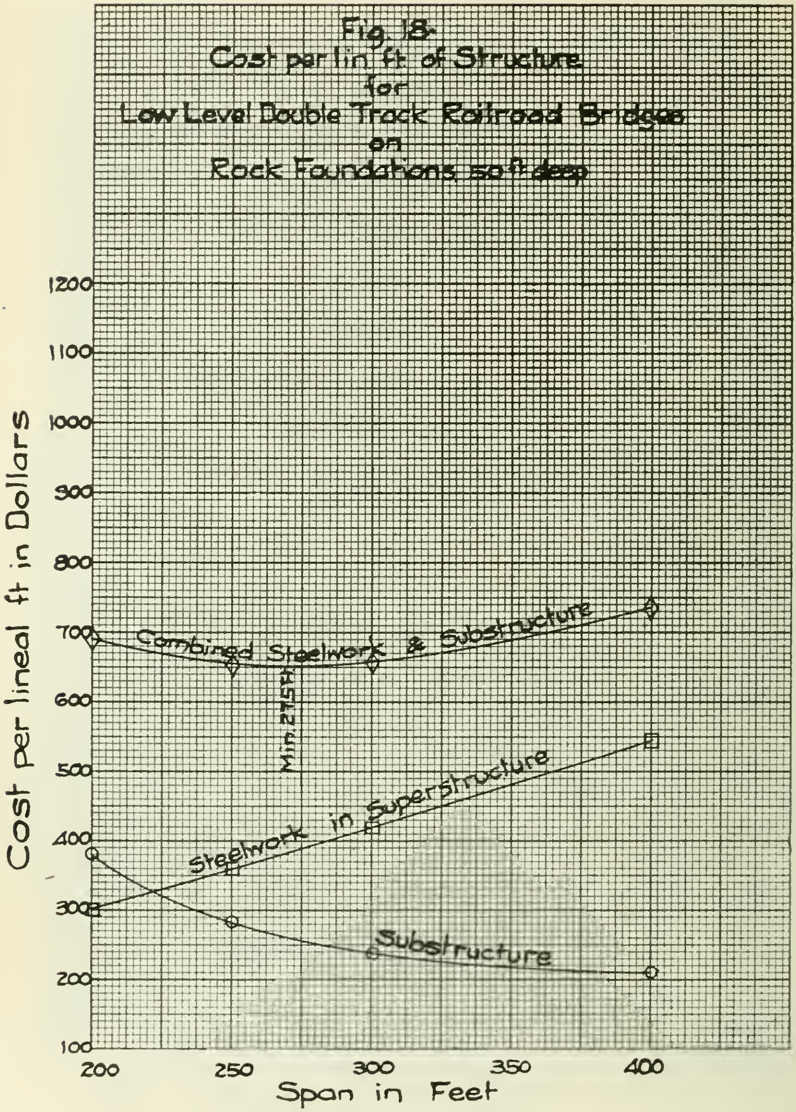


Fig. 18
Cost per lin. ft. of Structure
for
Low Level Double Track Railroad Bridges
on
Rock Foundations 50 ft deep
Cost per lineal ft in Dollars
1200
1100
1000
900
800
700
600
500
400
300
200
100
Combined Steelwork & Substructure
Min. 275 ft
Steelwork in Superstructure
Substructure
200
250
300
350
400
Span in Feet

Fig. 18

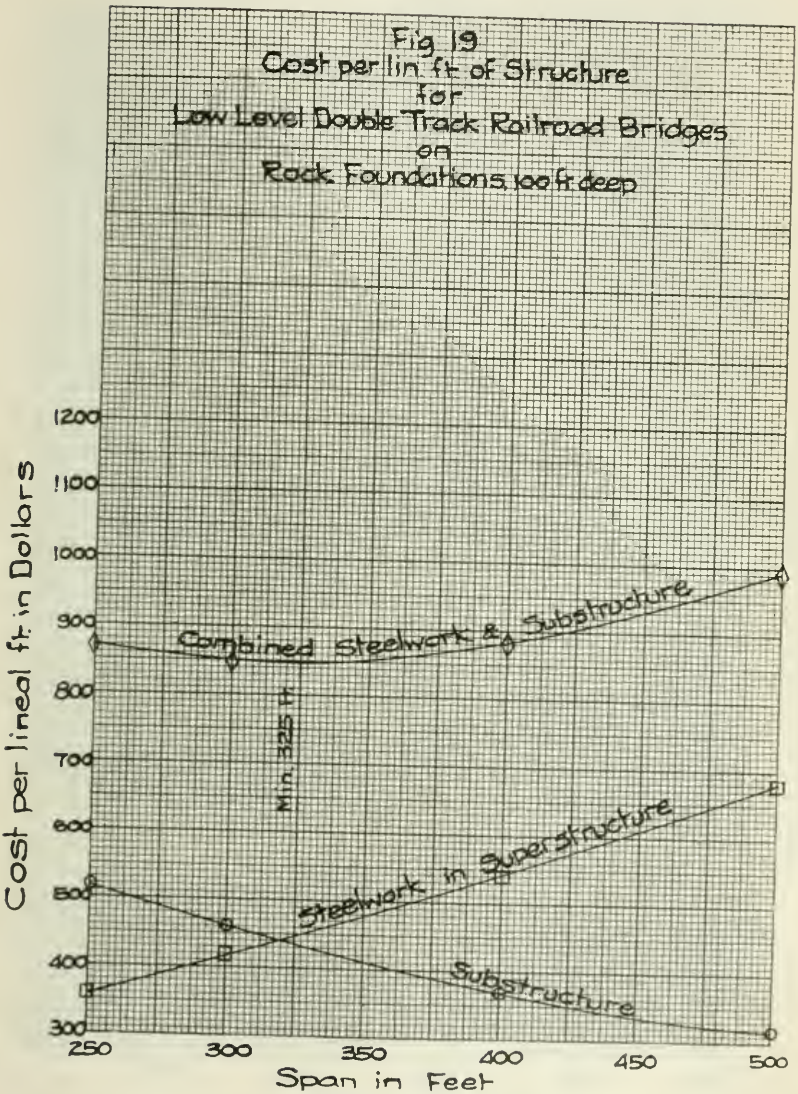


Fig. 19
Cost per lin. ft. of Structure
for
Low Level Double Track Railroad Bridges
on
Rock Foundations 100 ft. deep
Cost per lineal ft. in Dollars
1200
1100
1000
900
800
700
600
500
400
300
250
300
350
400
450
500
Span in Feet
Combined Steelwork & Substructure
Min. 325 ft.
Steelwork in Superstructure
Substructure

Fig. 19

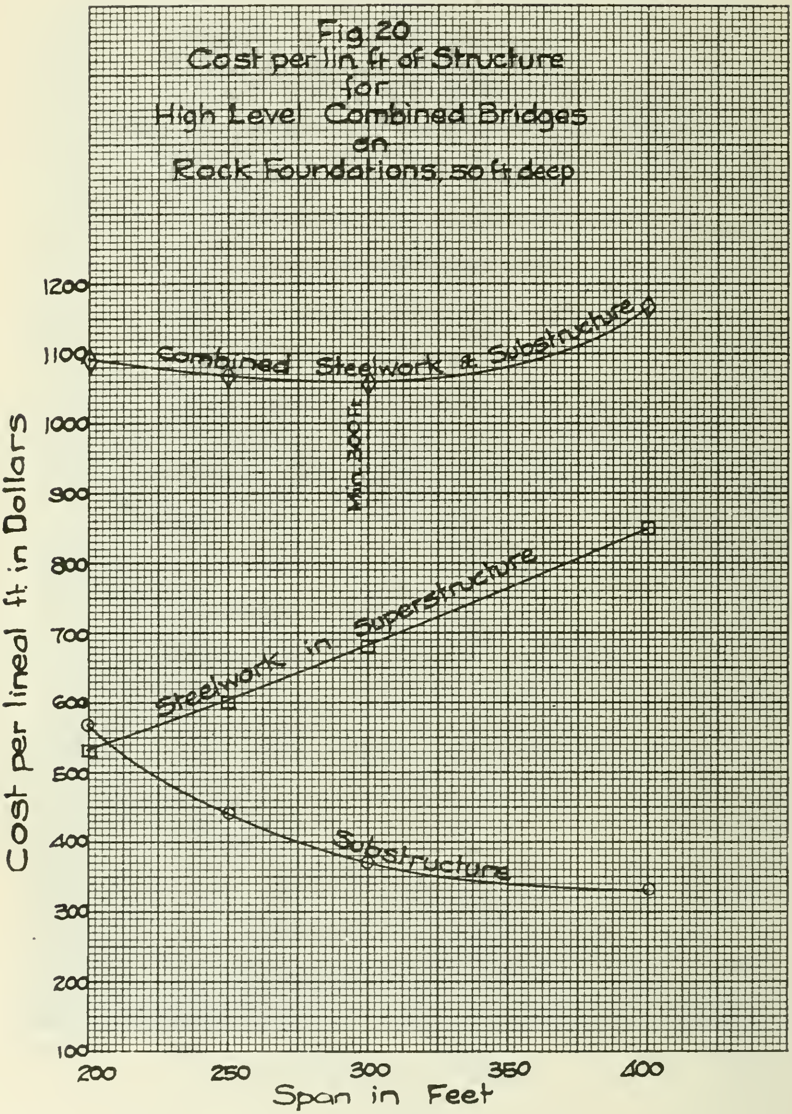


Fig 20
Cost per lin ft of Structure
for
High Level Combined Bridges
on
Rock Foundations, 50 ft deep
Combined Steelwork & Substructure
Min. 300 ft
Steelwork in Superstructure
Substructure
Cost per lineal ft. in Dollars
1200
1100
1000
900
800
700
600
500
400
300
200
100
200
250
300
350
400
Span in Feet

Fig. 20

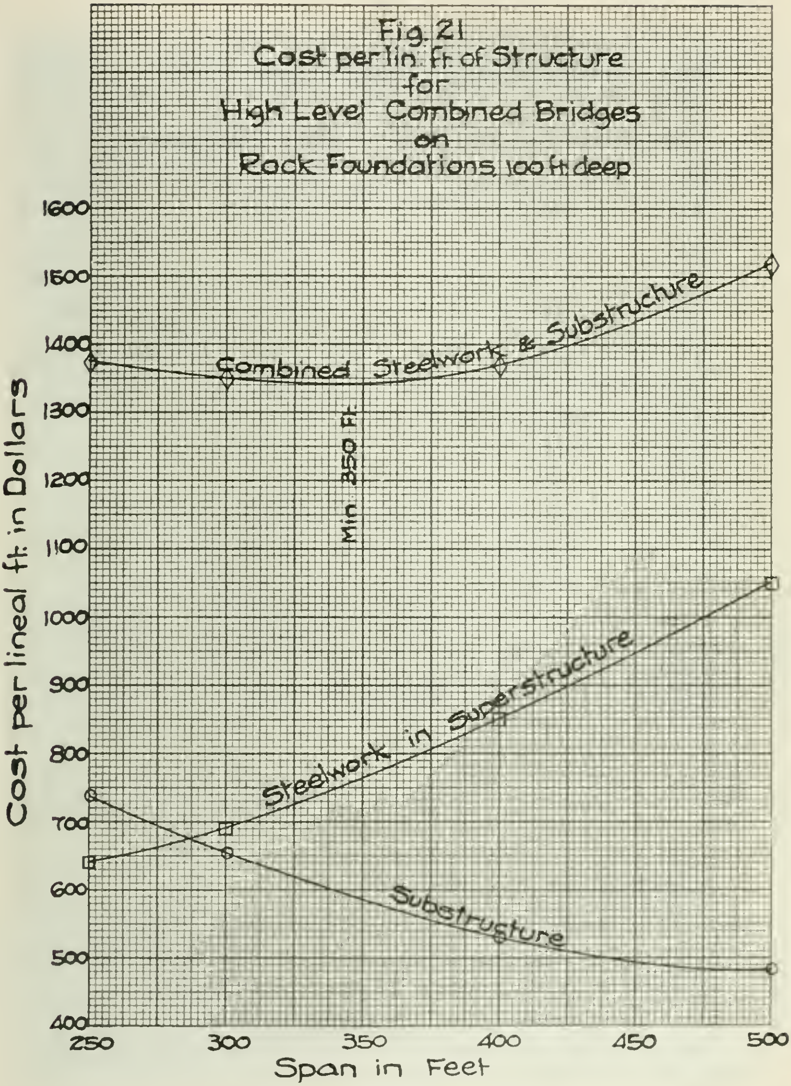


Fig. 21
Cost per lin. ft. of Structure
for
High Level Combined Bridges
on
Rock Foundations, 100 ft. deep
Cost per lineal ft. in Dollars
Combined Steelwork & Substructure
Min. 350 Ft.
Steelwork in Superstructure
Substructure
Span in Feet
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
250
300
350
400
450
500

Fig. 21

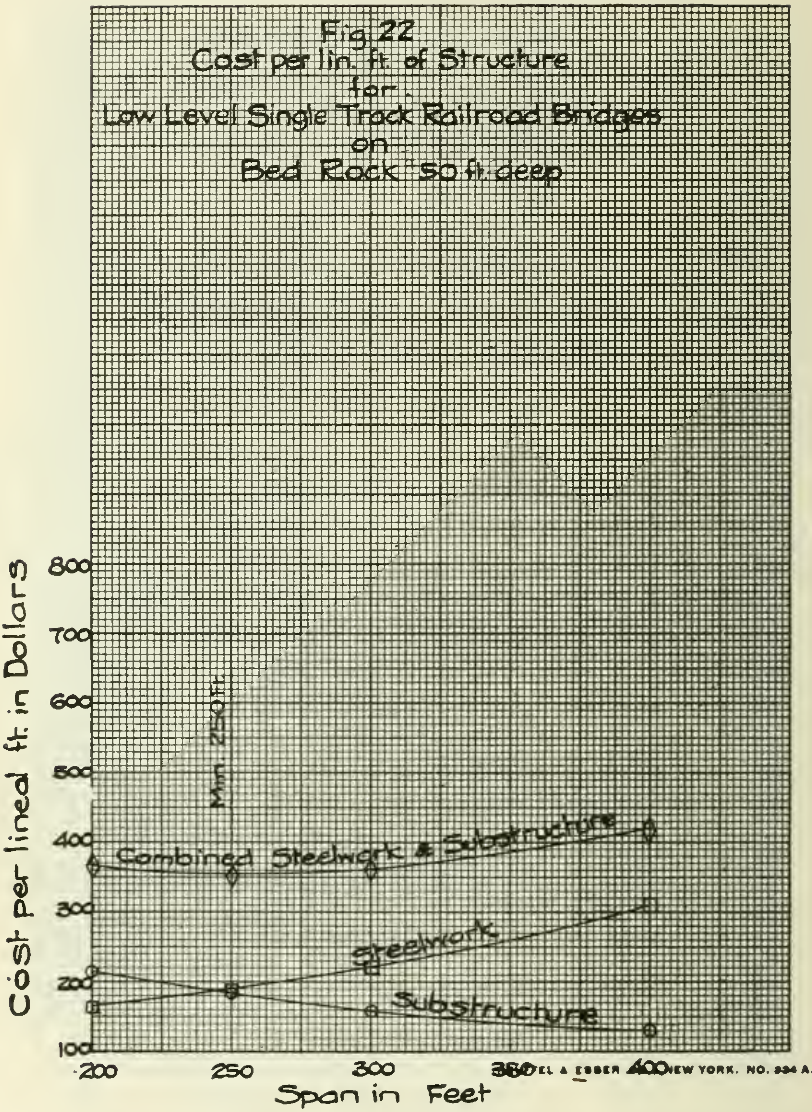


Fig. 22
Cost per lin. ft. of Structure
for
Low Level Single Track Railroad Bridges
on
Bed Rock 50 ft. deep
Min. 250 ft.
Combined Steelwork & Substructure
Steelwork
Substructure
Cost per lineal ft. in Dollars
800
700
600
500
400
300
200
100
200
250
300
350
400
Span in Feet

Fig. 22

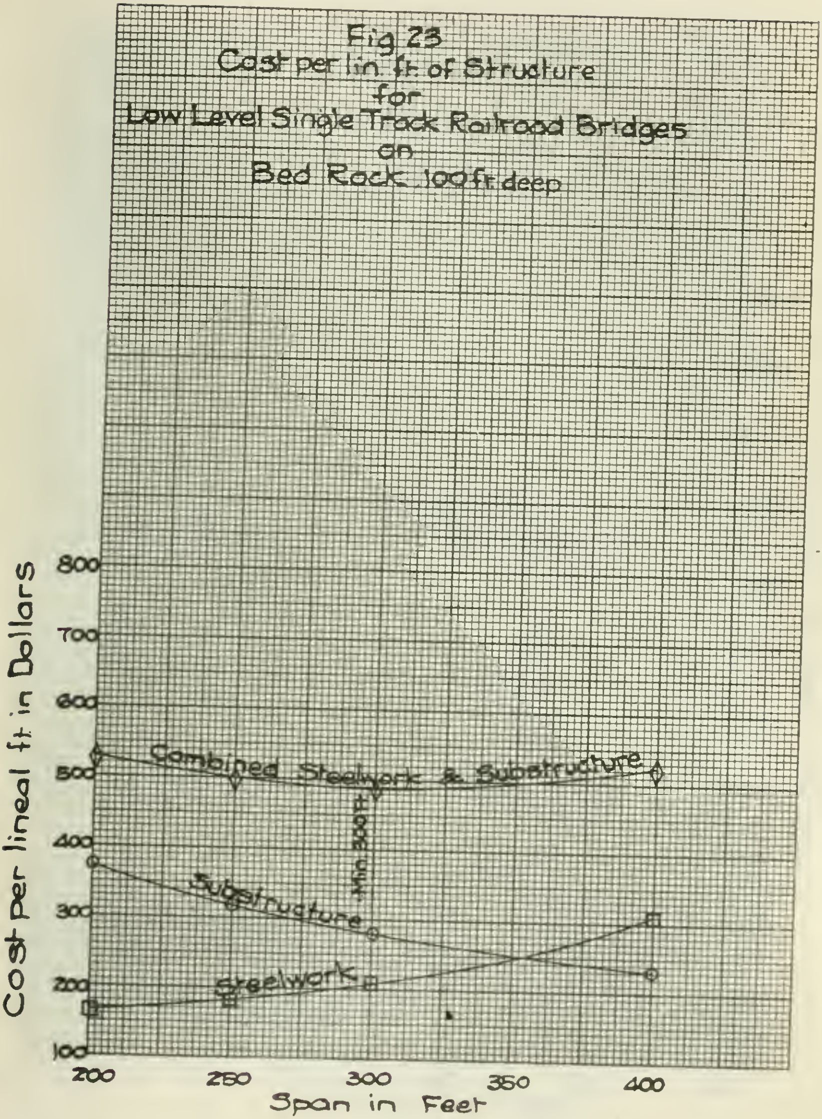


Fig 23
Cost per lin. ft. of Structure
for
Low Level Single Track Railroad Bridges
on
Bed Rock 100 ft. deep
Cost per lineal ft. in Dollars
800
700
600
500
400
300
200
100
Combined Steelwork & Substructure
Min 300 ft
Substructure
Steelwork
200
250
300
350
400
Span in Feet

Fig. 23

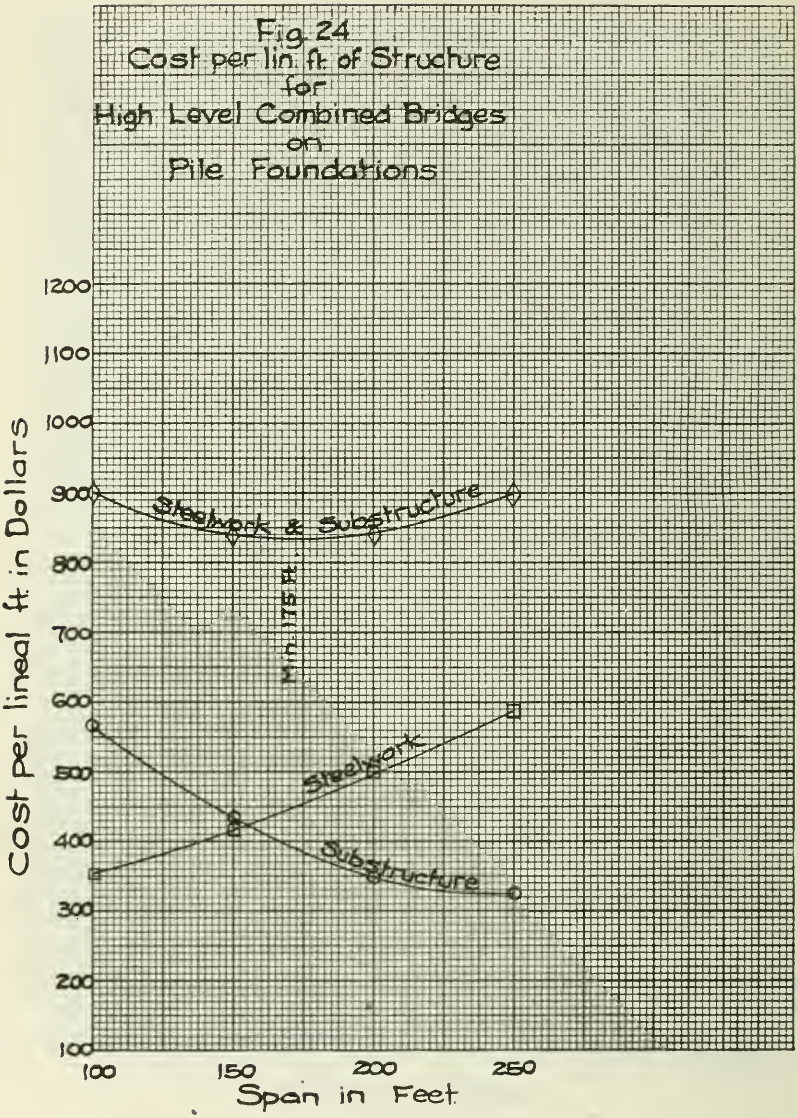


Fig. 24
Cost per lin. ft. of Structure
for
High Level Combined Bridges
on
Pile Foundations
1200
1100
1000
900
800
700
600
500
400
300
200
100
Cost per lineal ft. in Dollars
Steelwork & Substructure
Min. 175 Ft.
Steelwork
Substructure
100
150
200
250
Span in Feet

Fig. 24

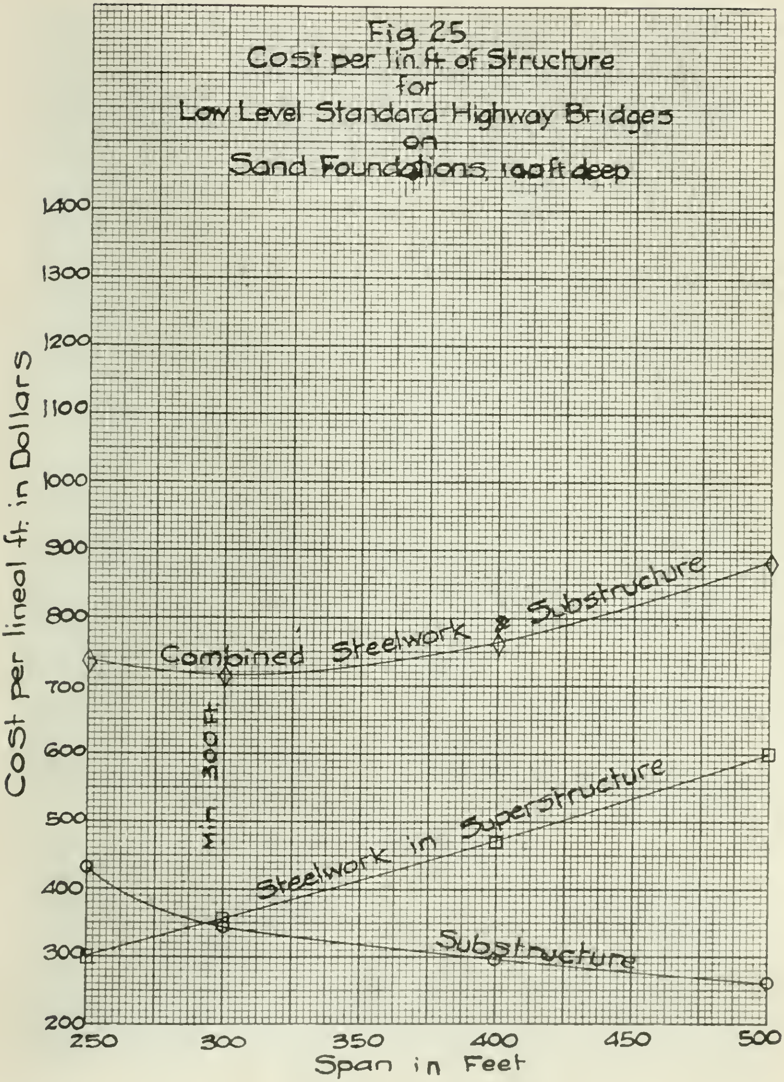


Fig. 25
Cost per lin. ft. of Structure
for
Low Level Standard Highway Bridges
on
Sand Foundations, 100 ft deep
Cost per lineal ft. in Dollars
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
250
300
350
400
450
500
Span in Feet
Combined Steelwork & Substructure
Min. 300 Ft.
Steelwork in Superstructure
Substructure

Fig. 25

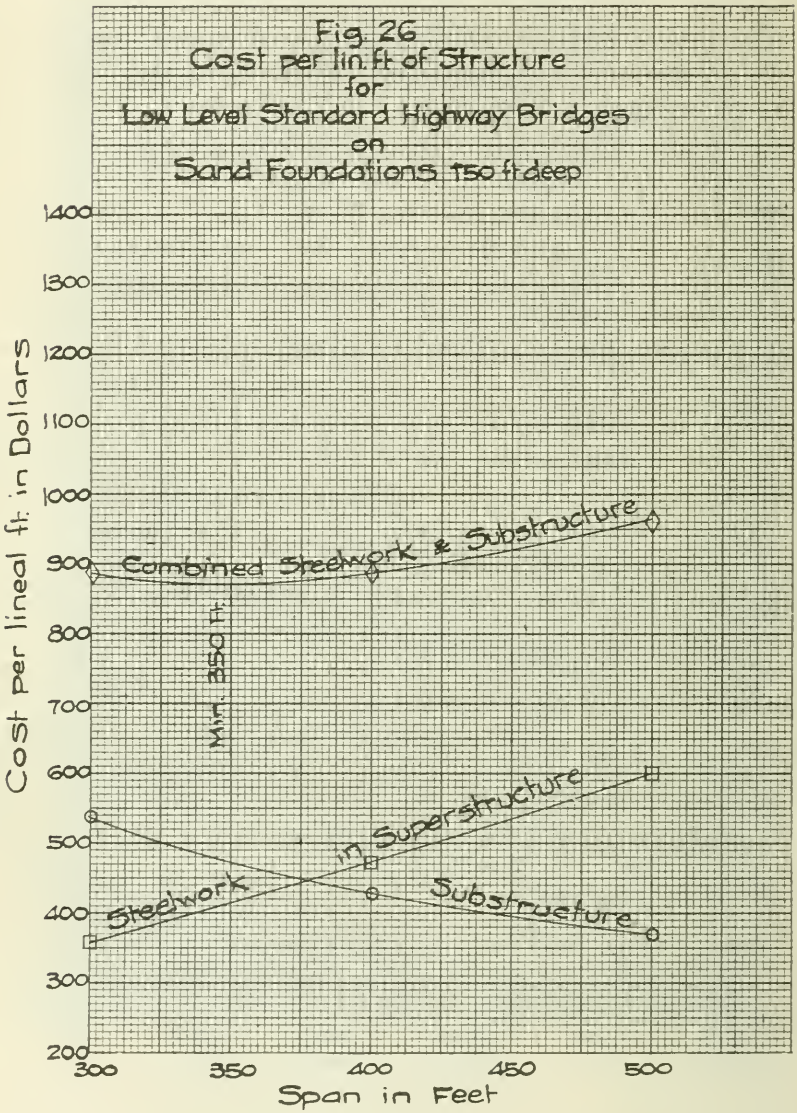


Fig. 26
Cost per lin. ft. of Structure
for
Low Level Standard Highway Bridges
on
Sand Foundations 150 ft. deep
Cost per lineal ft. in Dollars
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
300
350
400
450
500
Span in Feet
Combined Steelwork & Substructure
Min. 350 ft.
Steelwork in Superstructure
Substructure

Fig. 26

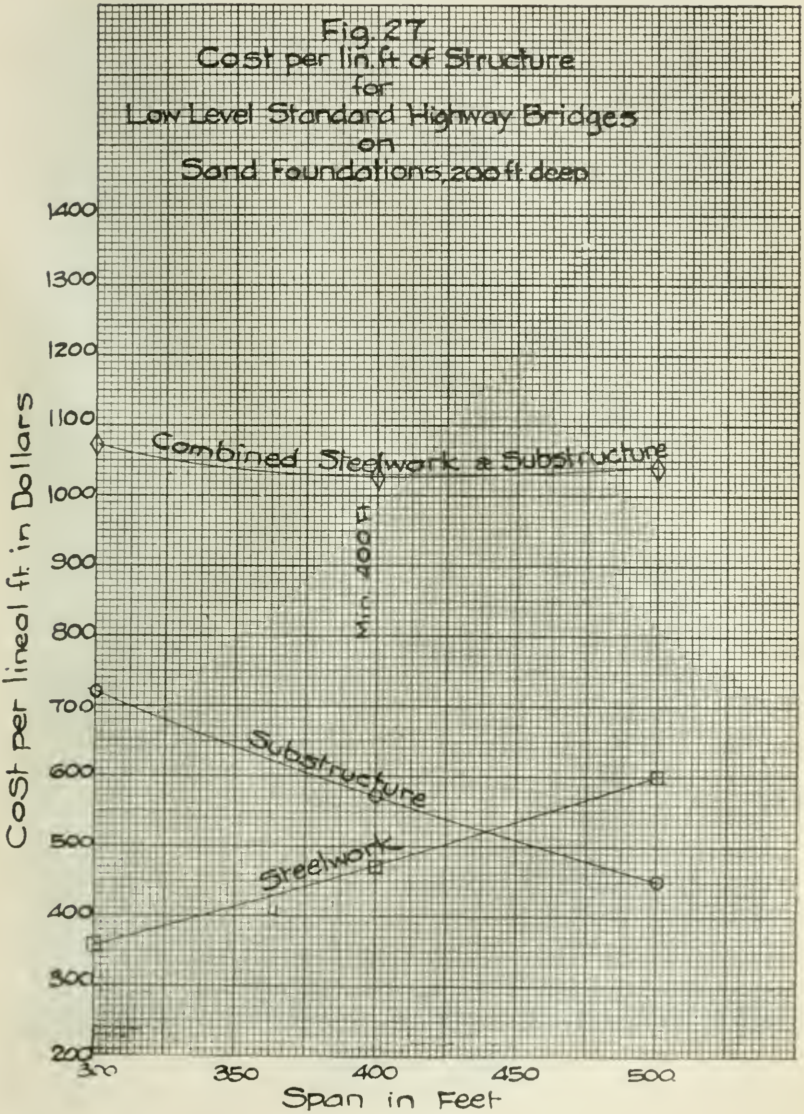


Fig. 27
Cost per lin. ft of Structure
for
Low Level Standard Highway Bridges
on
Sand Foundations, 200 ft deep
Combined Steelwork & Substructure
Min. 400 ft
Substructure
Steelwork
Cost per lineal ft. in Dollars
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
300
350
400
450
500
Span in Feet

Fig. 27

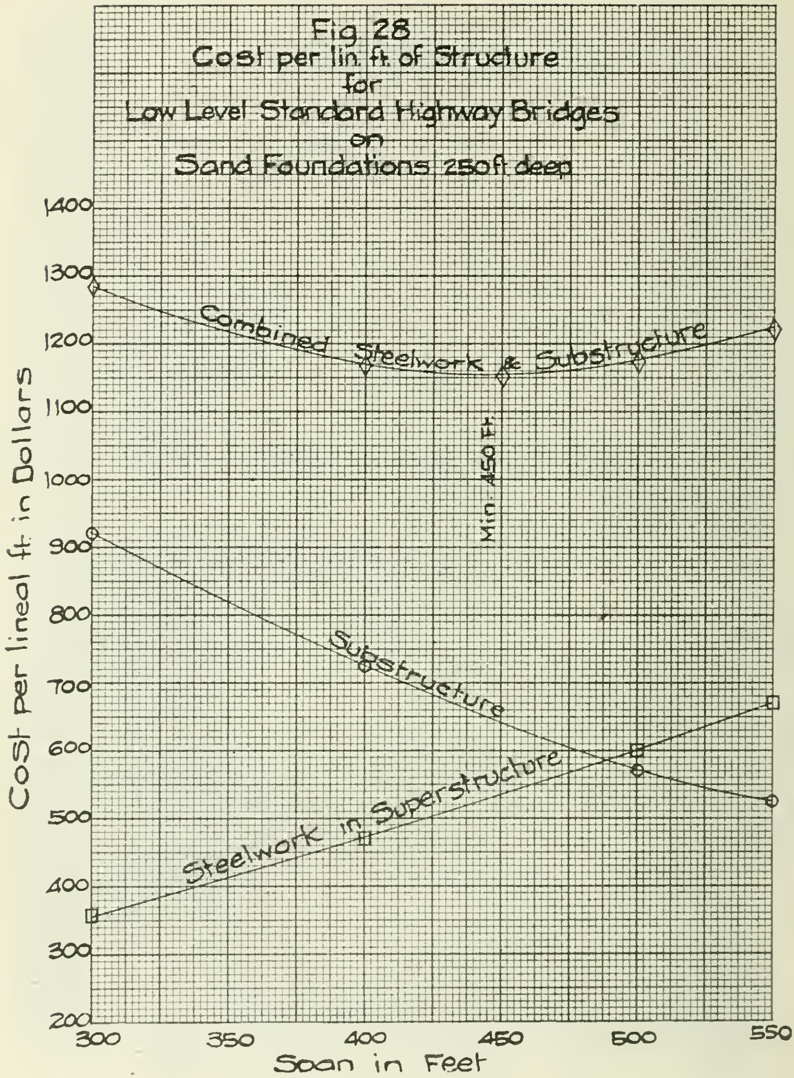


Fig 28
Cost per lin. ft. of Structure
for
Low Level Standard Highway Bridges
on
Sand Foundations 250ft deep
Cost per lineal ft. in Dollars
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
Combined Steelwork & Substructure
Min. 450 Ft.
Substructure
Steelwork in Superstructure
300
350
400
450
500
550
Soan in Feet

Fig. 28

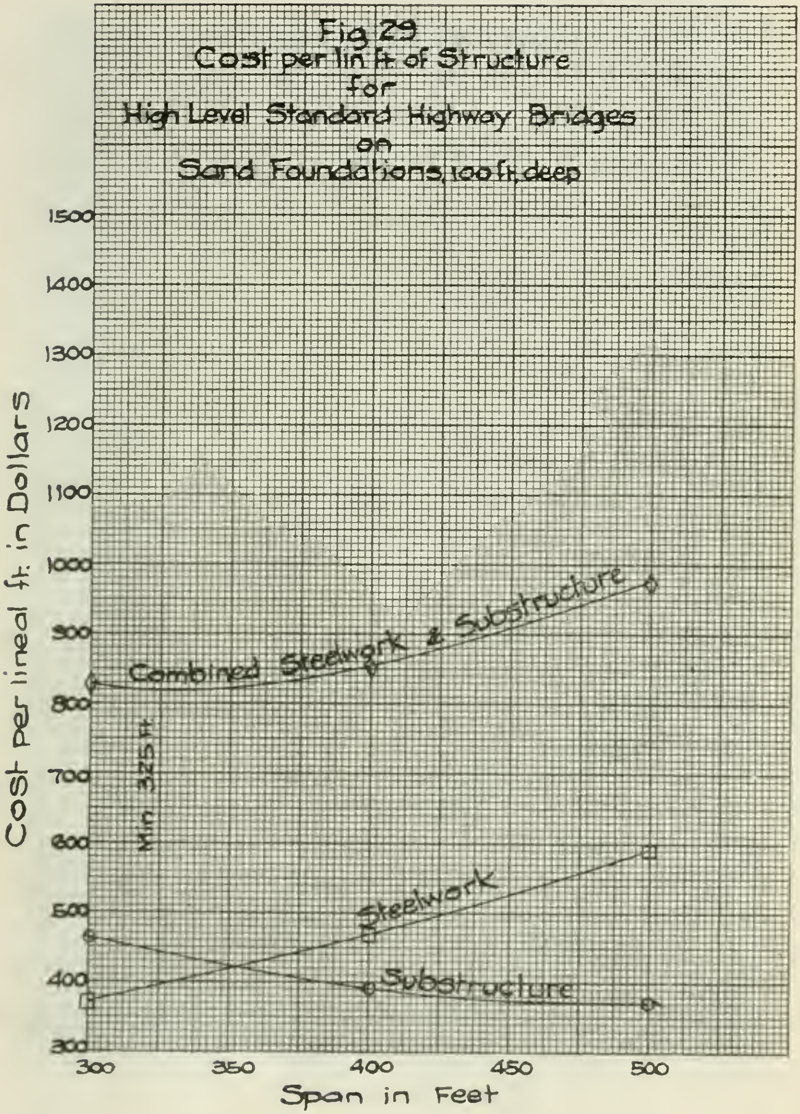


Fig 29
Cost per lin ft of Structure
for
High Level Standard Highway Bridges
on
Sand Foundations, 100 ft deep
Cost per lineal ft. in Dollars
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
Combined Steelwork & Substructure
Min. 325 ft
Steelwork
Substructure
300
350
400
450
500
Span in Feet

Fig. 29

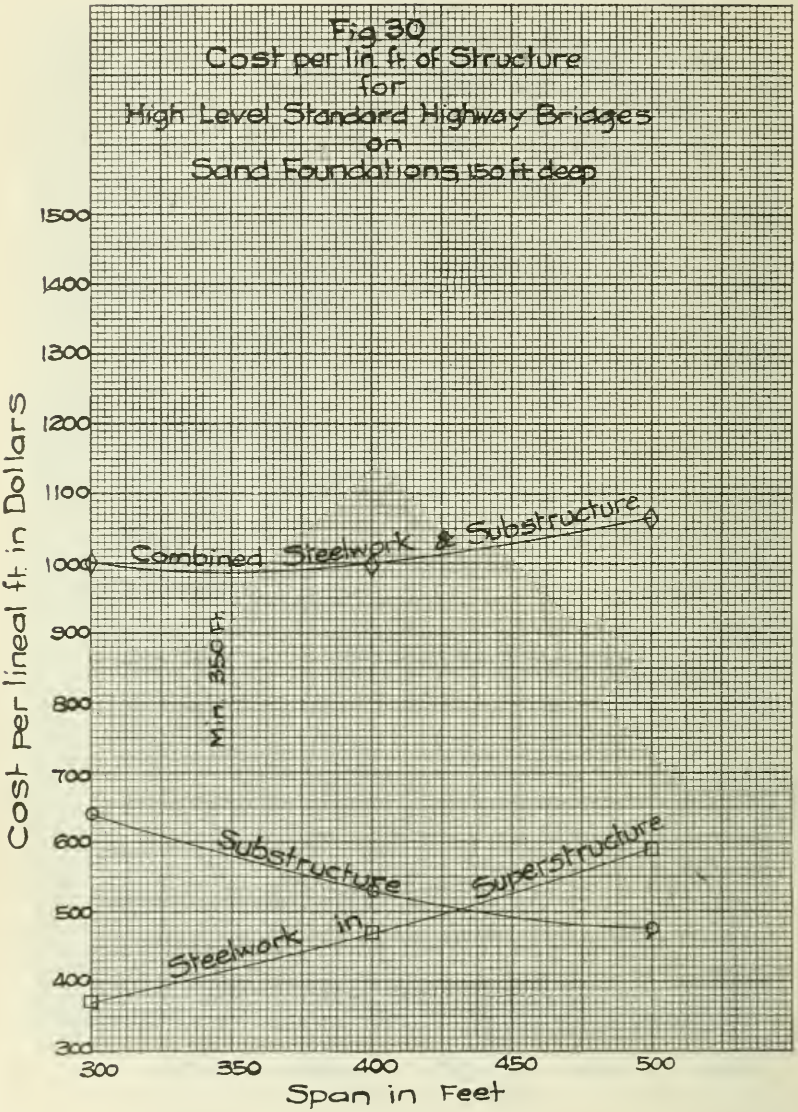


Fig 30
Cost per lin ft of Structure
for
High Level Standard Highway Bridges
on
Sand Foundations 150 ft deep
Cost per lineal ft in Dollars
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
Combined Steelwork & Substructure
Min. 350 ft
Substructure
Superstructure
Steelwork in
300
350
400
450
500
Span in Feet

Fig. 30

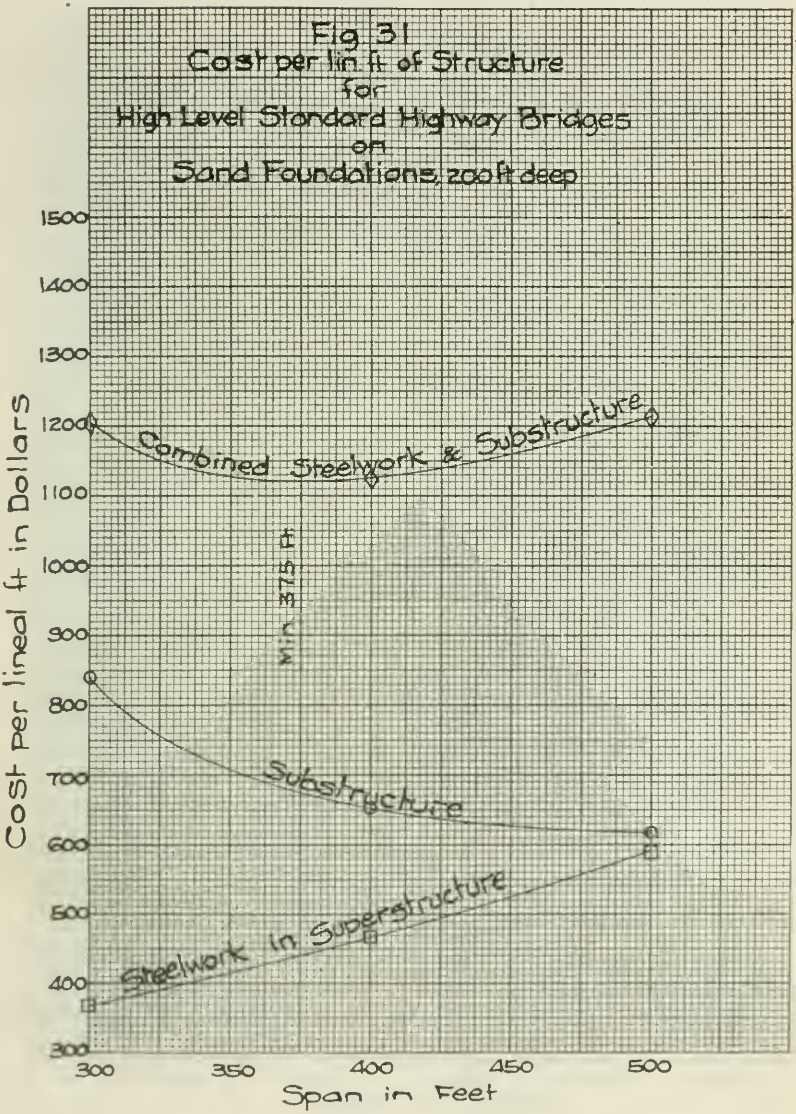


Fig 31
Cost per lin. ft. of Structure
for
High Level Standard Highway Bridges
on
Sand Foundations, 200 ft deep
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
Cost per lineal ft in Dollars
Combined Steelwork & Substructure
Min 375 ft
Substructure
Steelwork in Superstructure
300
350
400
450
500
Span in Feet

Fig. 31

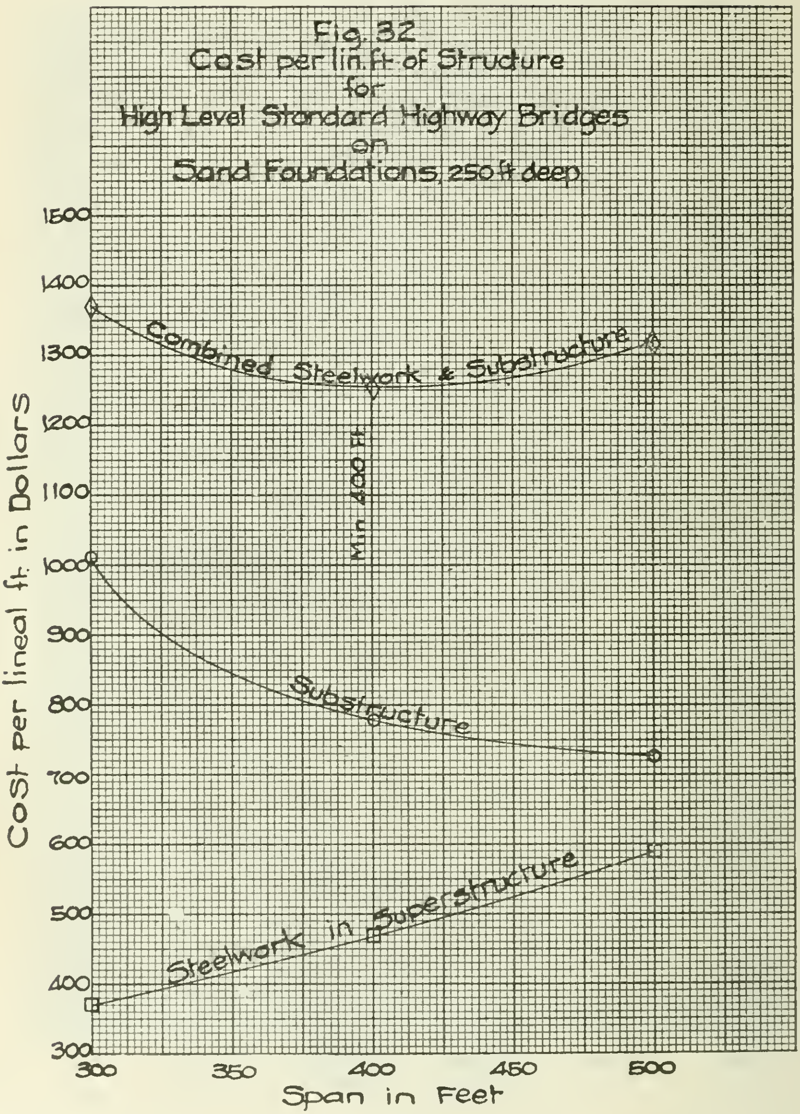


Fig. 32
Cost per lin. ft. of Structure
for
High Level Standard Highway Bridges
on
Sand Foundations, 250 ft deep.
Combined Steelwork & Substructure
Min 400 ft
Substructure
Steelwork in Superstructure
Cost per lineal ft. in Dollars
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
300
350
400
450
500
Span in Feet

Fig. 32

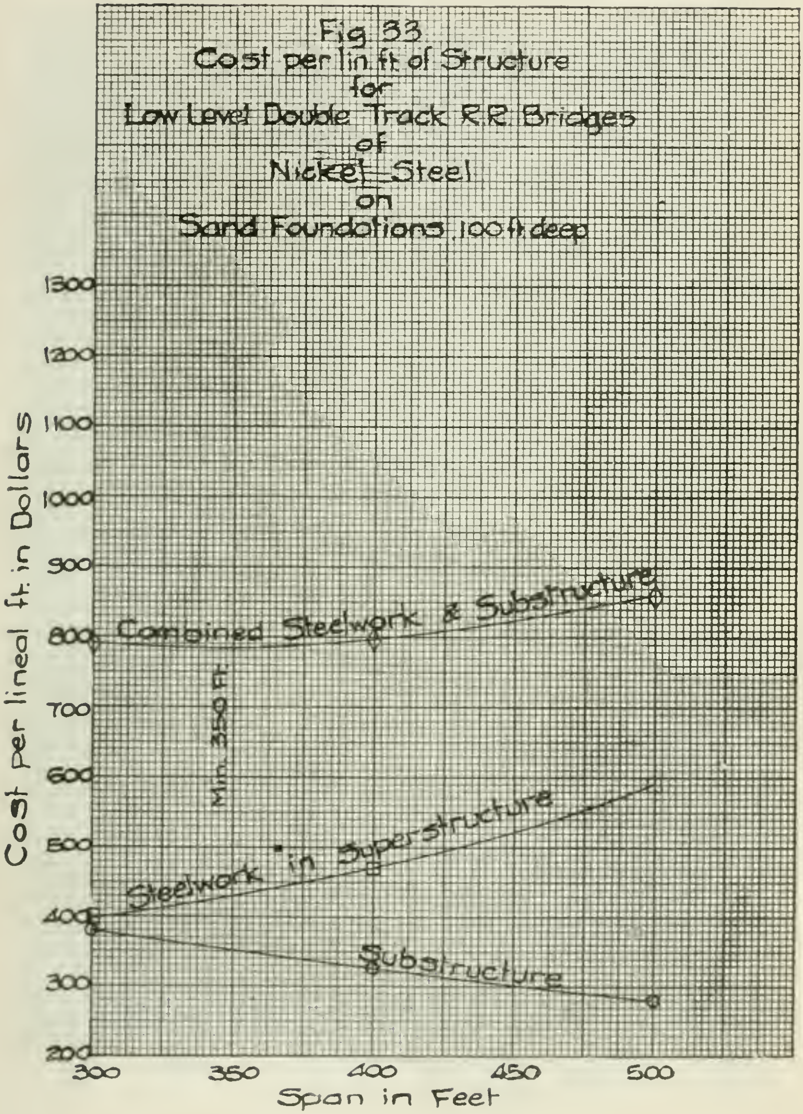


Fig 33
Cost per lin ft of Structure
for
Low Level Double Track R.R. Bridges
of
Nickel Steel
on
Sand Foundations 100 ft deep
Cost per lineal ft. in Dollars
1300
1200
1100
1000
900
800
700
600
500
400
300
200
Combined Steelwork & Substructure
Min. 350 ft
Steelwork in Superstructure
Substructure
300
350
400
450
500
Span in Feet

Fig. 33

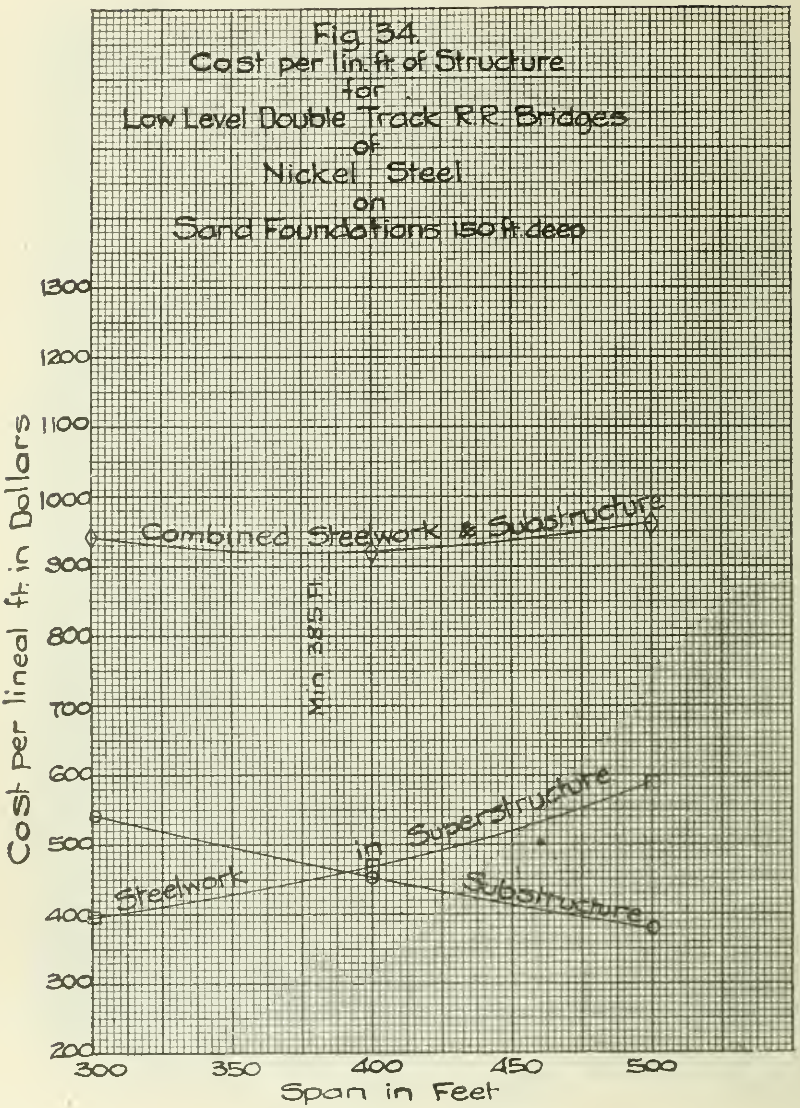


Fig. 34.
Cost per lin. ft. of Structure
for
Low Level Double Track R.R. Bridges
of
Nickel Steel
on
Sand Foundations 150 ft. deep
Cost per lineal ft. in Dollars
1300
1200
1100
1000
900
800
700
600
500
400
300
200
300
350
400
450
500
Span in Feet
Combined Steelwork & Substructure
Min. 385 Ft.
Steelwork in Superstructure
Substructure

Fig. 34

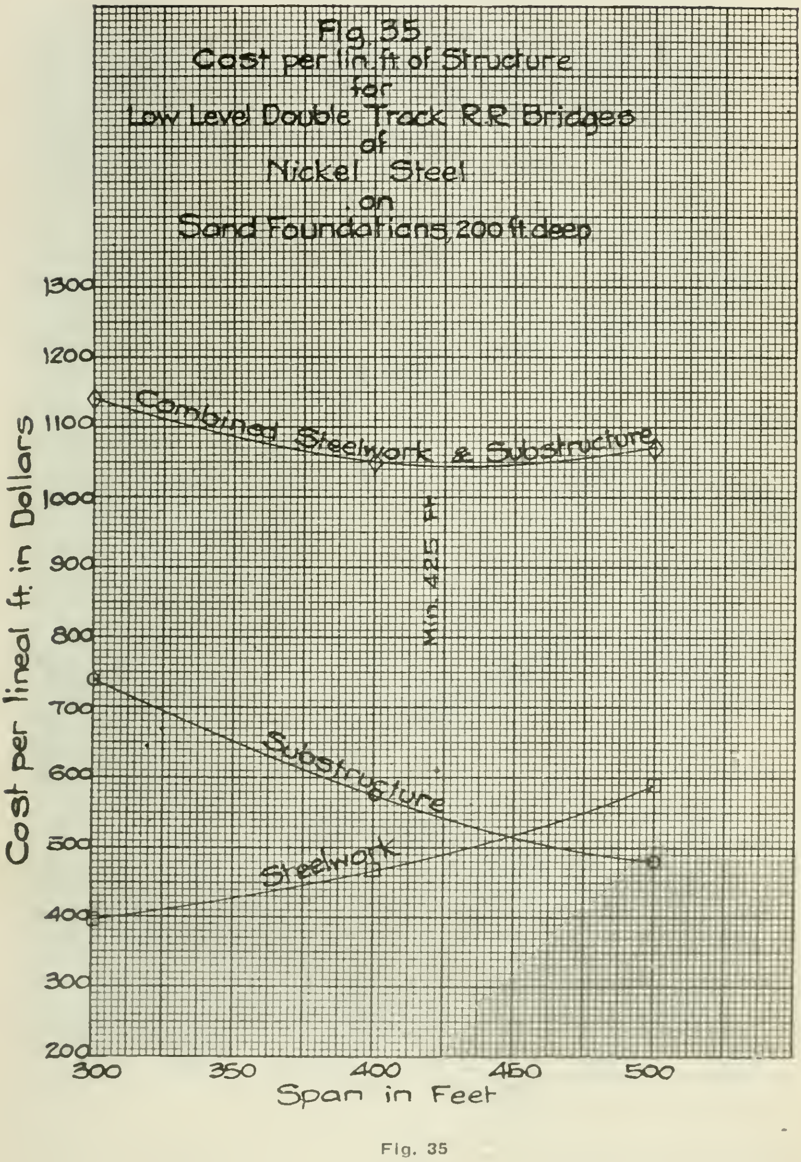


Fig. 35
Cost per lin. ft. of Structure
for
Low Level Double Track R.R. Bridges
of
Nickel Steel
on
Sand Foundations, 200 ft. deep
Combined Steelwork & Substructure
Min. 425 Ft.
Substructure
Steelwork
Cost per lineal ft. in Dollars
1300
1200
1100
1000
900
800
700
600
500
400
300
200
300
350
400
450
500
Span in Feet

Fig. 35

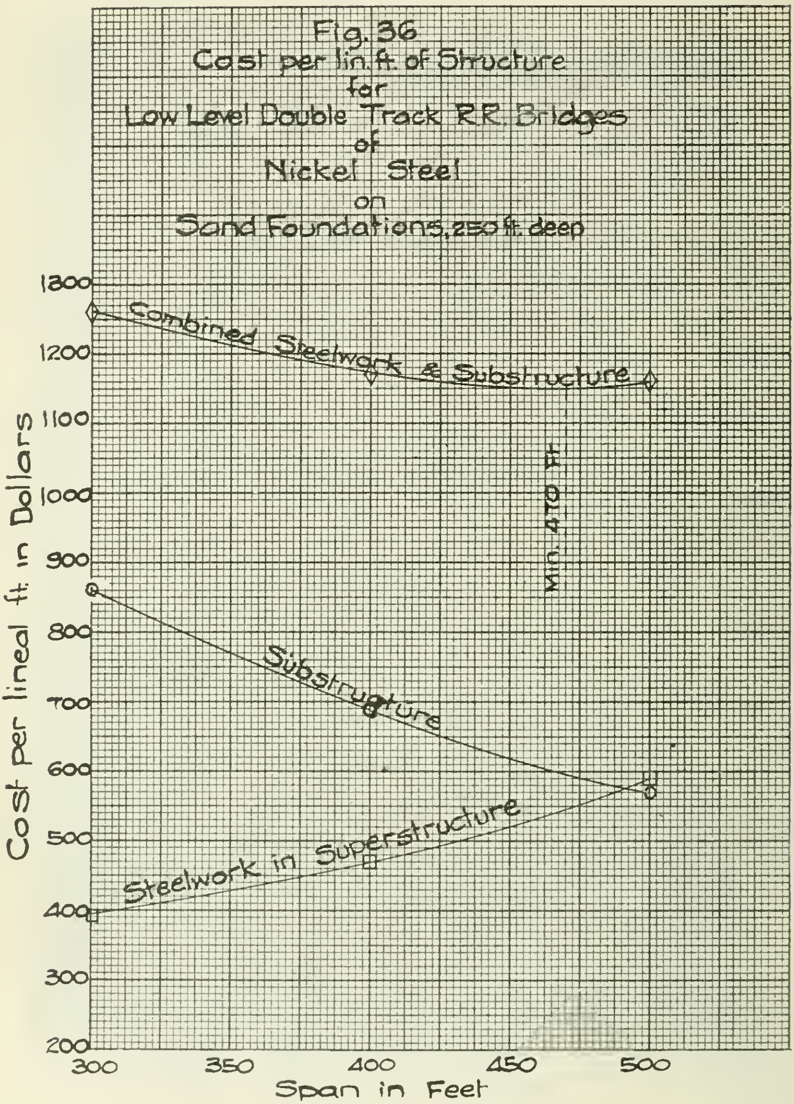


Fig. 36
Cost per lin. ft. of Structure
for
Low Level Double Track R.R. Bridges
of
Nickel Steel
on
Sand Foundations, 250 ft. deep
Combined Steelwork & Substructure
Substructure
Steelwork in Superstructure
Min. 470 Ft.
Cost per lineal ft. in Dollars
1300
1200
1100
1000
900
800
700
600
500
400
300
200
300
350
400
450
500
Span in Feet

Fig. 36

Proceedings of the Society

Meeting No. 1037, April 7, 1919.

This was ladies' night, under the auspices of the entertainment committee, A. W. Dilling, chairman, and 164 members and guests were present. A very interesting program was presented by the committee. This was introduced by a moving picture entitled "Almost a Mason." Music of the evening consisted of instrumental and vocal numbers by the Armour Institute Glee and Madolin clubs. Lieut. Albert Hassell, Company E. 23rd Infantry, A. E. F., described his experiences in the front line trenches. Light refreshments were served.

Meeting No. 1038, April 14, 1919.

This was a meeting of the Bridge and Structural engineering section, G. A. Haggander, chairman, presiding. The meeting was attended by 55 members and guests. Clyde Pyle, manager of erection, McClintic Marshall Construction Company, Pittsburgh, Pa., presented a paper describing the erection of the Sciotoville bridge by the C. & O. N. Railway over the Ohio river. This was illustrated with numerous lantern slides. The erection features of this bridge were very novel and a departure from former methods. This was due to the design of the bridge and the requirements of the United States Government.

Meeting No. 1039, April 21, 1919.

This was a joint meeting of the Mechanical Engineering section, W. S. E., and the Chicago section, A. S. M. E. The meeting was attended by 260 members and guests. F. J. Postel, chairman, presided. Robert J. Young, manager, department of safety and relief, Illinois Steel Company, presented a moving picture of the Triplex process of making steel. These pictures were explained by Mr. Young and included the entire process from the unloading of the ore and through the blast furnaces, the Bessemer converter, the open hearth furnaces and the refinement of the metal in the electric furnace. Prof. Herbert F. Moore, department of experimental engineering, University of Illinois, presented a paper on "The Fatigue of Metals." This was illustrated with moving pictures taken through the microscope, showing the development of fracture under repeated loading. Micro-photographs were also shown, showing the structure of steel and the development of fracture under breaking tests.

Meeting No. 1040, April 28, 1919.

This was a joint meeting of the Electrical Engineering section, W. S. E., and Chicago section, A. I. E. E., and was attended by 225 members and guests. A. A. Oswald, engineer, Western Electric Company, New York City, gave an address on "Wireless Telephony and Telegraphy in the War." Mr. Oswald was research engineer on development of wireless apparatus. The nominating committee of the Chicago section, A. I. E. E., made their report.

EDGAR S. NETHERCUT, *Secretary.*

Book Reviews

United States Rifles and Machine Guns. By Fred H. Colvin and Ethan Vaill, Associate Editors of *American Machinist*. A detailed account of the methods used in manufacturing the Springfield 1903 Model, Service rifle. Also contains descriptions of the Modified Enfield rifle and three types of machine guns. 339 pages, 8¾ by 11½ inches, illustrated. Published by McGraw-Hill Book Co., New York. Price, $3.00.

In the preface, the authors explain the purpose and uses of their work. It is one of a series of similar works undertaken for the purpose of assisting manufacturers in undertaking large contracts with the U. S. Government for manufacture of Ordnance Supplies. This particular volume has to do with the operations in the fabrication of the Springfield, Model 1903, Service rifle.

The title of the book would lead the reader to expect a greater amount of detail concerning the other arms than is given. However, the description, and that is all that it is, given of each of the other guns is interestingly written and has a special educational value at this time. U. S. Automatic Machine Rifle, Cal. 30, Model 1909, Lewis Machine Gun and Vickers Machine Gun, Model 1915, are three types of machine guns described. Drawings and photographs serve to enlighten the reader on these types of guns and together with the written description, they afford a real education in machine gun design and operation. The short description of the Modified Enfield rifle, now known as the U. S. Model 1917, shows the great similarity between this gun and the Springfield, Model 1903. The contrasting points between these two rifles are also set forth but the reader or student will feel that the description is all too short.

The major portion of the volume is taken up with the description of the details of the manufacture of the Springfield, Model 1903. All operations are set forth in a short, concise manner. Data on machinery and tools, rate of operations and operators are defined for each step in the process of manufacture. Every part of the rifle from tip of bayonet to butt plate meet the same treatment and the evolution from raw material to finished product is as clearly outlined as though seen on a trip of inspection through a well equipped plant.

The drawings and perspectives present remarkably clear detail of many operations and their use is one of the repeated good features of the book. The benefit to be derived from such a book is not limited to the manufacturers of rifles. Indeed, as stated by the preface concerning the possible benefit to be derived by manufacturers from the description of machine uses, the use of such clear drawings and perspectives should be of great benefit to those who may undertake similar volumes in the future.

As a record of the operations and their details the book is remarkably complete. It is evident, however, that its usefulness to possible manufacturers of this arm will entail careful study and analysis. Widely divergent rates of operation and length of operations will require careful grouping and operation of machines to secure a real plant efficiency.

In following the various steps in the manufacture of the various parts, the reader is impressed with the large number of "fussy little milling cuts and similar operations." It is evident that the development of milling machines and tools has been utilized to a maximum in this work. Indeed, to the casual reader, it appears that the milling machine is the principal machine used.

The historical data and photographs showing the evolution of the American military rifle form a very interesting addition to such a technical volume. The story there told is of value to a real "gun enthusiast" or patriot.

H. E. H

JOURNAL OF THE
WESTERN SOCIETY of ENGINEERS

VOLUME XXIV MAY, 1919 NUMBER 5

Sewerage, Sanitation and Reclamation at U. S. Army Camps

By MAJOR LEONARD J. DOTEN,
Construction Division, Quartermaster Corps, U. S. A.

Presented February 17, 1919.

THE contrast between the armies of the past and the armies developed during the present war appeals very strongly to the speaker.

The military forces of all nations previous to the war and the combat troops of this war have been trained chiefly in the art of destruction. Whatever the compensating factors may be eventually, we must recognize a great economic loss as the immediate result of war. Therefore, we say war and waste are synonymous.

There are many compensating factors for the wastefulness of war. We readily recognize some of them. The people of this

Main distributor and laterals in filter bed, Fort Sheridan General Hospital No. 28, Sewage Disposal Plant.

country have accomplished much in conserving labor, essential materials, food and fuel.

Notwithstanding the traditions of military organizations and the great effort to train a vast army for successful military opera-

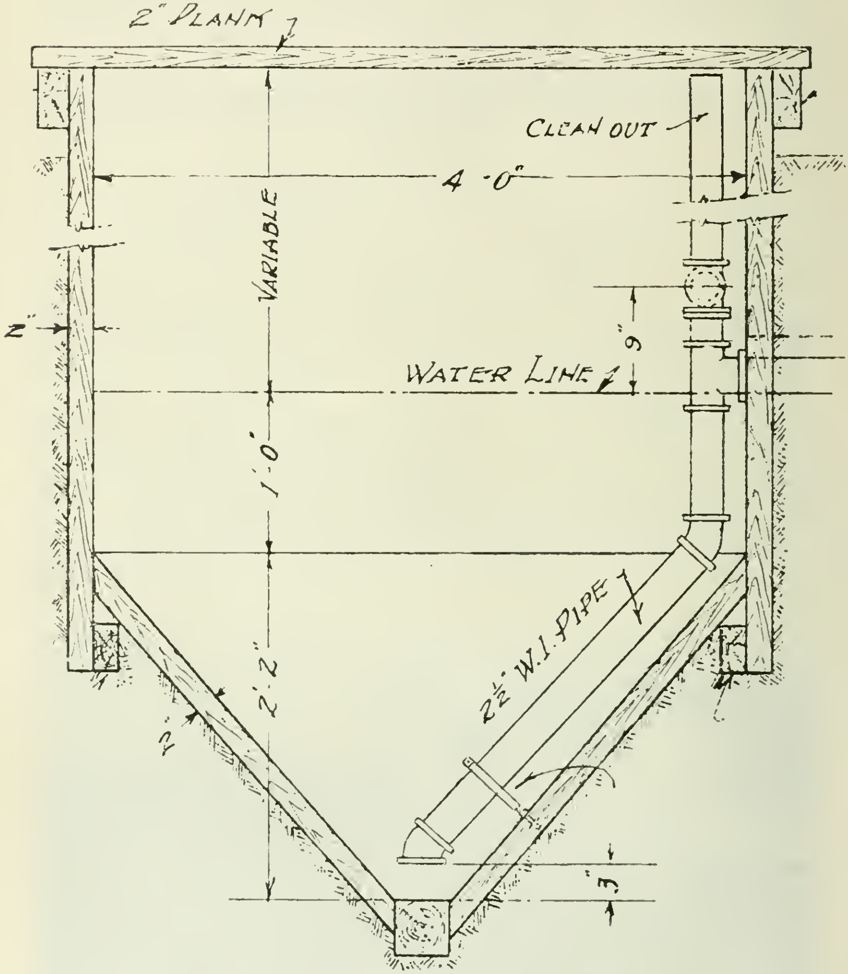
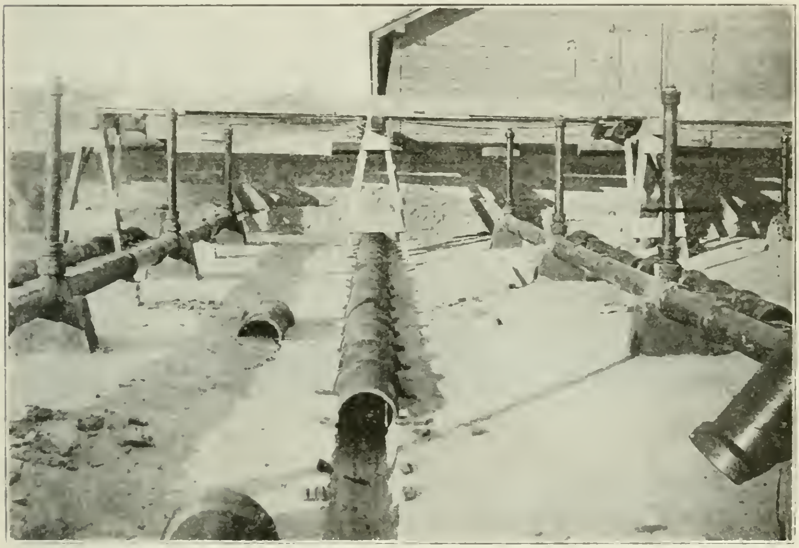


Fig. 1. Standard Grease Trap, Capacity 200 Gallons—250 Men

tions, the War Department has accomplished wonderful results in the conservation of its resources in men and material. This has been the result largely of the adoption of economic principles in production and construction, and of the strict adherence to laws of hygiene and sanitation. In this connection the work instituted and accomplished by the construction division is especially noteworthy.

Among the earliest problems dealt with in outlining the construction work for the military camps were water supplies, sewerage, drainage, and the economic disposal of waste. These problems were of even greater importance in preserving the health of the troops than the construction of barracks, for it should be borne in mind that a large number of the camps in this country were provided only with tents for the shelter of troops. The engineers of the construction division were mindful of the insanitary conditions in military camps of former wars, and they resolved that history should not repeat itself in this respect.



Under drains and risers in filter bed, Fort Sheridan General Hospital No. 28, Sewage Disposal Plant.

The development of the camps and cantonments in this country was original in character. It was largely the result of experience gained by the War Department in establishing and maintaining camps along the Mexican border during the past four or five years. The scheme as originally outlined by the construction division consisted of the construction of thirty-two divisional cantonments, each cantonment to be fully equipped with water supply and sewerage systems. Only sixteen of these cantonments were authorized. The other sixteen camps which were used by the National Guard were authorized as tent camps on the assumption that they would be more temporary in character than the cantonments for the National Army, which were first authorized.

These tent camps, together with many other smaller camps, were provided with water distributing systems and shower bath equipment, but water carriage sewerage was not authorized until

the spring of 1918. It has been found by experience that unless soil and climatic conditions are especially favorable, it is impossible to maintain a camp in a first class sanitary condition for a period of over one year. For this reason, the construction of sewerage systems for this class of camps was strongly urged by the construction division during the winter of 1917-18. This work was completed during the past season.

The cantonments and nearly all of the camps not only were provided with complete sewerage and ample supplies of potable water, but with installations of adequate plumbing equipment and an effective system of collection and disposal of wastes. A large amount of drainage work within the limits of and adjacent to the reservations has been carried out, together with other anti-malarial work in coöperation with the sanitary corps and the public health service. At several of the cantonments steam laundries and refrigerating plants have been installed.

As early as June, 1917, special study had been given to the problem of collection and disposal of garbage and other wastes at the camps, especially at the National Army cantonments. The scheme adopted for the cantonments consisted of the classification and separation of waste materials in such manner as to secure the greatest amount of revenue from the sale of the material. All wastes were collected by means of the duplicate can system. This was an important factor in camp sanitation, as it reduced to a minimum the fly nuisance by avoiding the strewing of waste organic matter on the grounds in the vicinity of company kitchens.

The garbage and other wastes were disposed of by sale to contractors. This resulted in a considerable revenue to the Government. Incineration of such materials, on the other hand, would have been very expensive and wasteful. The waste materials except manure, were delivered to the contractor at a transfer station located at a suitable distance from the barracks, and only such wastes as had no recoverable value were disposed of by incineration. At each of the transfer stations there was provided a small incinerator for the burning of wastes of no value.

The contractors in some cases disposed of the garbage by means of reduction plants where camps were located within a transportable distance of cities having plants of this kind, and in other cases the garbage was fed to hogs.

Shortly after this scheme was adopted and placed in operation by the construction division, a division was organized in the War Department, now known as the conservation and reclamation division, which took charge of the handling of these waste products and at a later date included reclamation and the disposal of other wastes, such as clothing, shoes, etc.

Previous to the signing of the armistice it was estimated that the revenue to the Government from the sale of such wastes as

bottles, tin cans, bones, fats, grease and manure at the camps would amount to over one million dollars per annum, the total for the months of July, August, September and October, 1918, being $360,570.

This method of collection and disposal of wastes has necessitated the development of plans for transfer stations which provide the best possible facilities for transferring the wastes from Government vehicles to contractors' equipment, for the rapid cleansing of garbage cans, and suitable incinerating equipment for the burning of unsaleable wastes.

It had been anticipated that, owing to the high market prices for grease, that a considerable revenue would be obtained from sale

Filter bed in operation, Fort Sheridan General Hospital No. 28, Sewage Disposal Plant.

of grease recovered from kitchen waste water. Unfortunately, however, the commercial type of grease trap which was first adopted and installed was found to be inefficient. As a result, a comparatively small amount of grease was recovered. In many cases, the lateral sewers became coated with grease and much trouble was being experienced at the sewage disposal plants on account of the extremely high grease content of the sewage. This was the condition found in the early spring of 1918. As soon as this fact became known special study was given in the construction division to the grease problem, with the result that large grease intercepting chambers were constructed at some of the disposal plants and a special design of grease trap was developed for use at company kitchens. These traps have proven very satisfactory both as to maintenance and in the results. In some cases traps of a later design were installed on kitchen sewer connections at a point located between the old traps and the lateral sewer, the old traps being left in place.

It has been found, as a result of carefully noting the quantity of grease removed, both from the old and new traps, that the old traps intercept on an average about 10 per cent of the amount intercepted by the new traps which received the flow

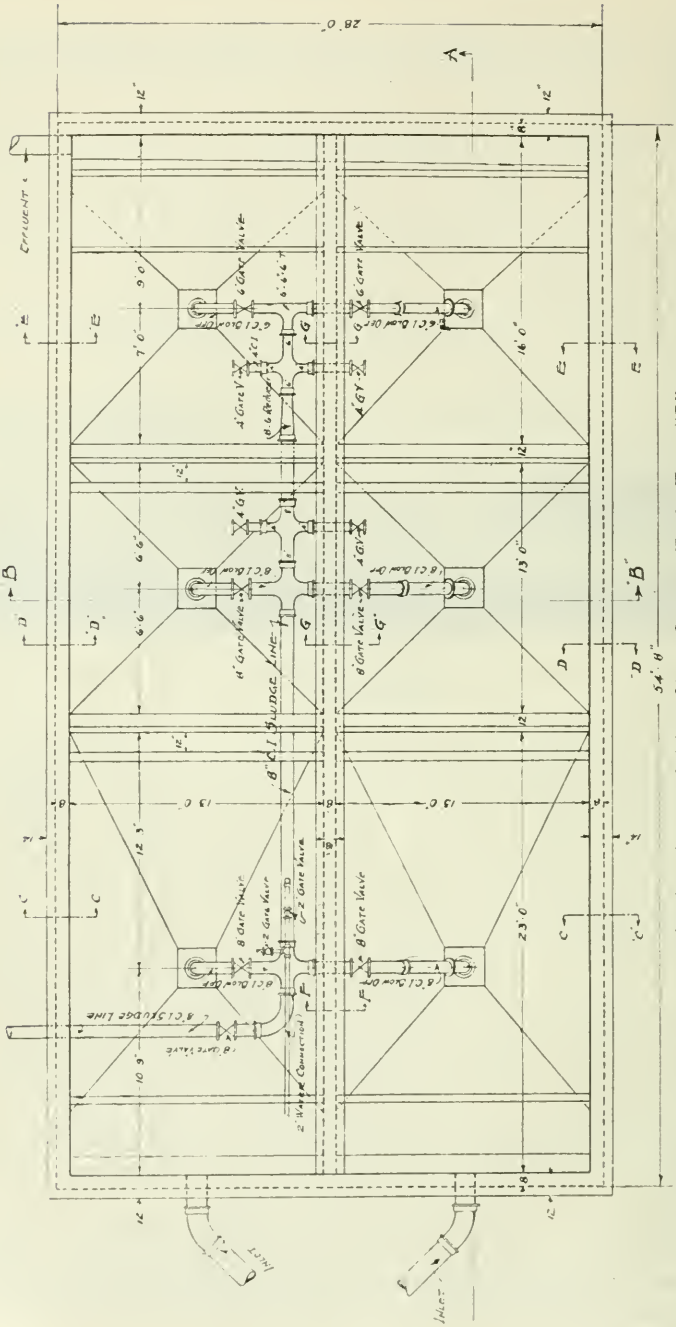


Fig. 4. Plan of Multiple Stage Sewage Tank, Type "B"

This tank is designed especially to reduce the operating cost to a minimum in treating sewage containing large quantities of scum forming material. It has a larger surface area and a greater sludge capacity in the first compartments than in the case of Type "A".

268 a

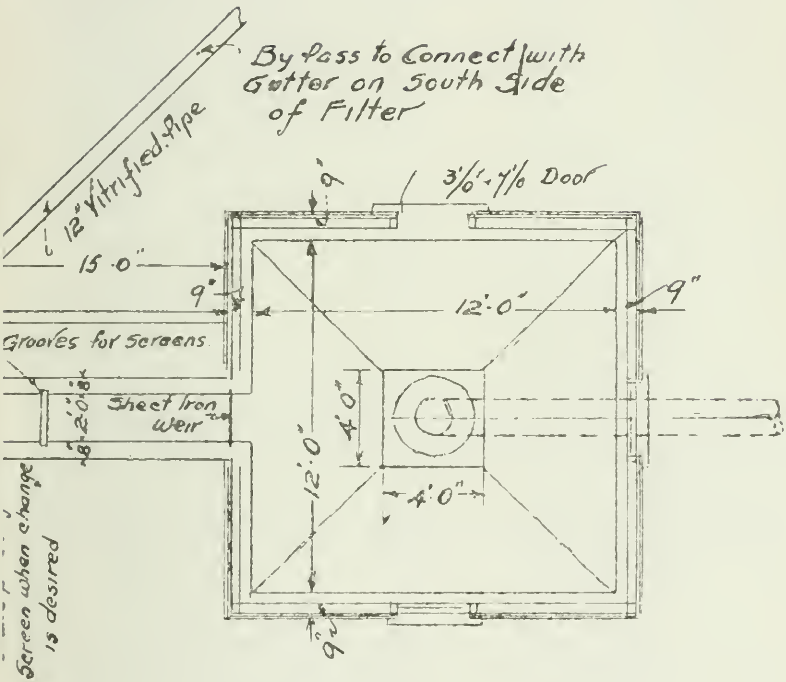
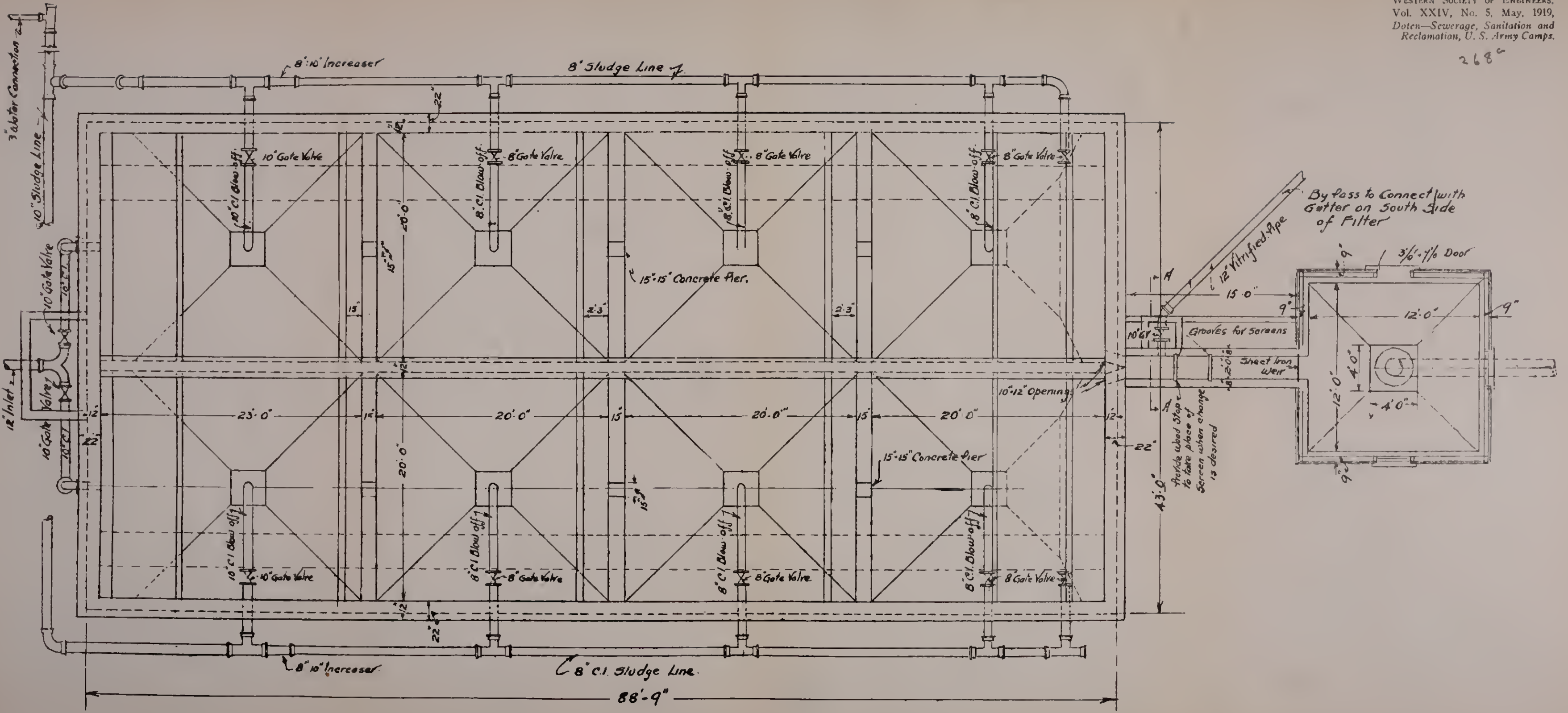

By Pass to Connect with Gutter on South Side of Filter
12" Vitrified Pipe
3'/0"×7'/0" Door
9"
15·0"
9"
12'·0"
9"
Grooves for Screens
Sheet Iron Weir
2'·0"
4'·0"
12'·0"
4'·0"
9"
Screen when change is desired

Fig. 2. Plan of Multiple Stage Sewage Tank, Type "A"



Western Society of Engineers,
Vol. XXIV, No. 5, May, 1919,
Doten—Sewerage, Sanitation and Reclamation, U. S. Army Camps.

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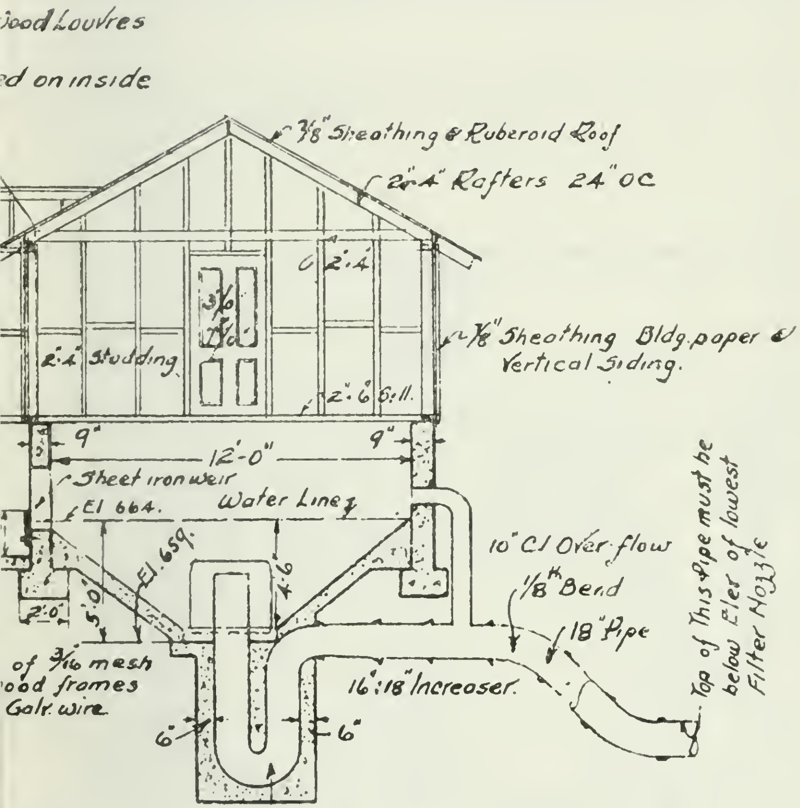


16" SIPHON

Fig. 3. Longitudinal Section, Multiple Stage Sewage Tank

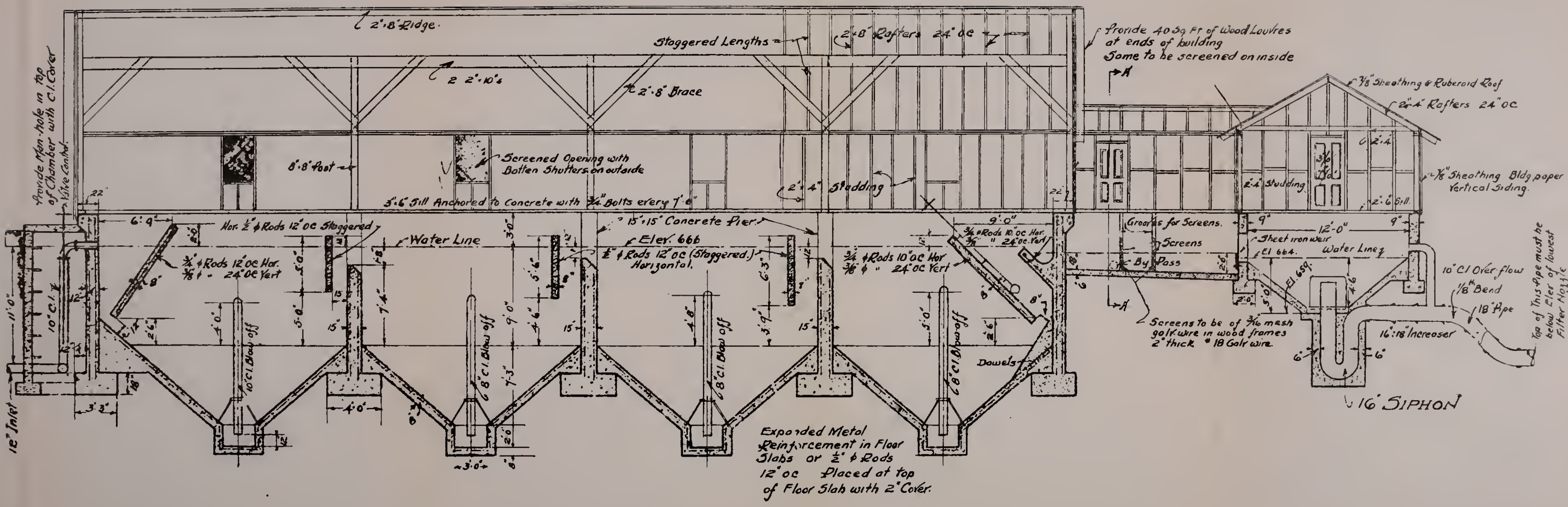
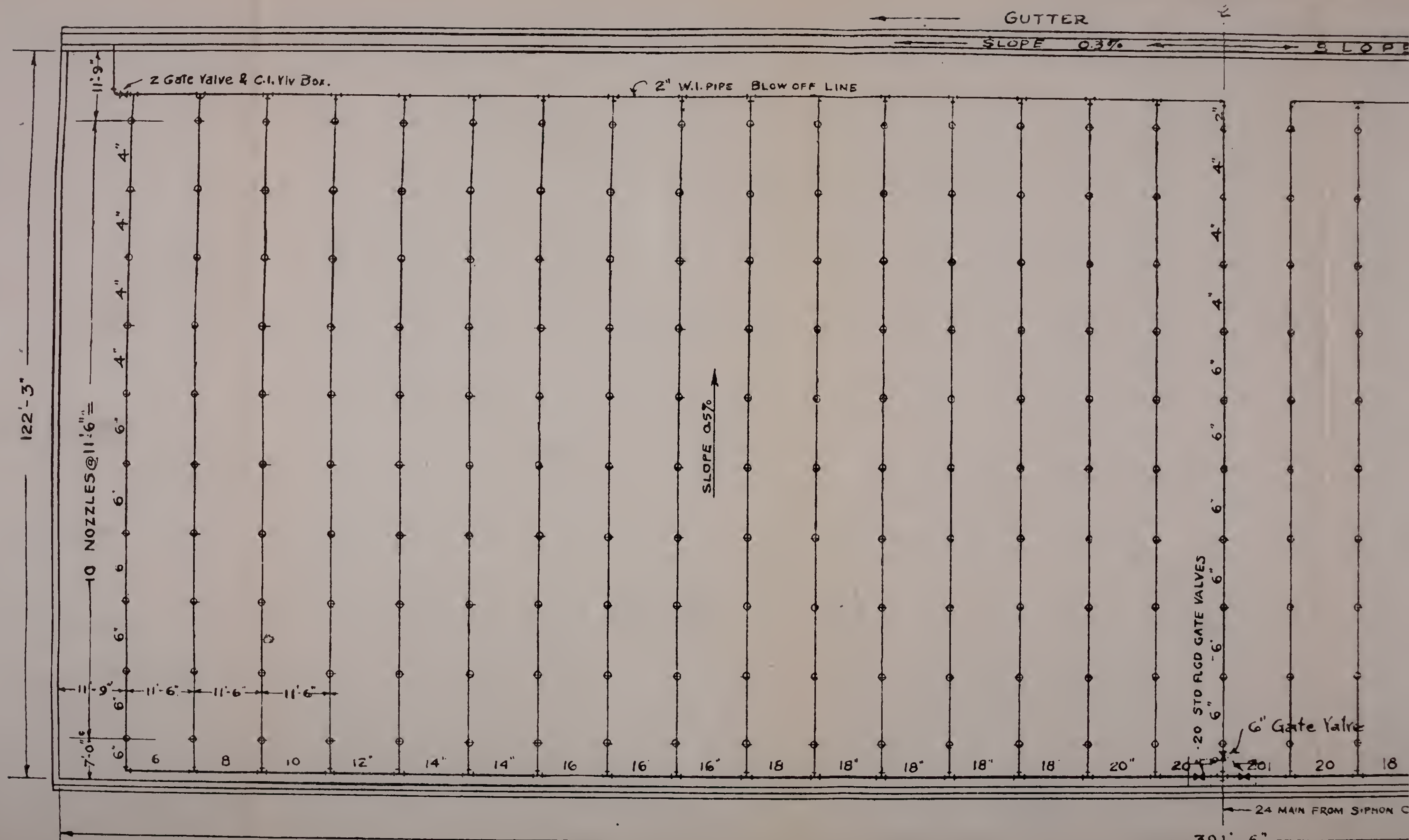
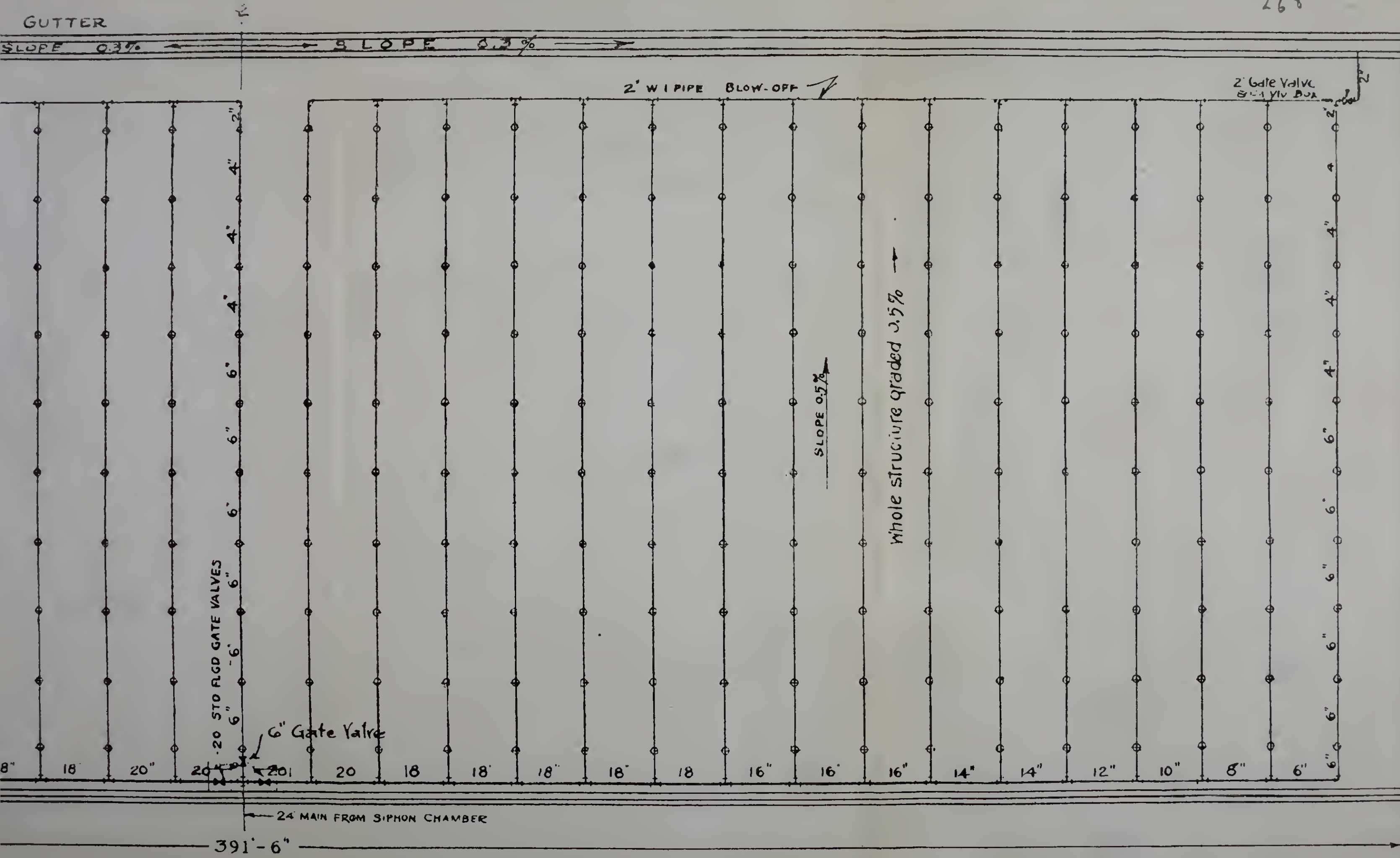


Fig. 9. Diagrammatic Plan, Standard Trickling Filter



268c

Fig. 9. Diagrammatic Plan, Standard Trickling Filter



passing through the old traps. Grease recoveries generally range from 10 pounds to 25 pounds per capita per year, 12 pounds to 14 pounds being a fair average for the camps. This grease in the crude state can be sold at prices ranging from three cents to eight cents per pound. After being properly rendered, the market price per pound ranges from ten cents to fifteen cents. It was estimated early in the season of 1918 that it would be practicable to secure a revenue of about $1 per man per year from the recovery of grease from the kitchen waste water. Data obtained since that date indicate that this estimate was quite conservative. Grease recovered by means of interceptors at treatment plants has no market value.

Filter bed, drainage gutter, septic tank and syhon house, Fort Sheridan General Hospital No. 28, Sewage Disposal Plant.

There have been many problems in sanitary engineering at the camps and cantonments which have differed widely from those found in municipalities. In the problem of sewage disposal it was found that the sewage is much more concentrated than the domestic sewage of municipalities. It has a very high grease content and contains an abnormally high quantity of organic suspended matter, consisting largely of paper, raw and cooked vegetables and rags. These factors are especially objectionable, rendering the treatment by means of tanks especially difficult. The grease content is from four to six times as high as that in average municipal sewage and the suspended organic matter nearly four times as high as the average of nine large American cities. It is approximately twice as great as the quantity found in the average of a group of English cities where the sewage is especially concentrated.

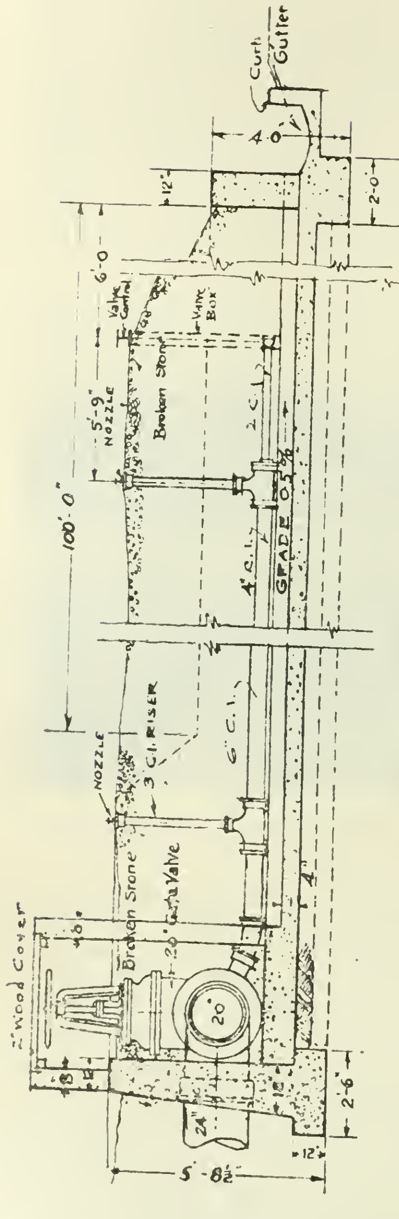


Fig. 5. Transverse Section, Standard Trickling Filter

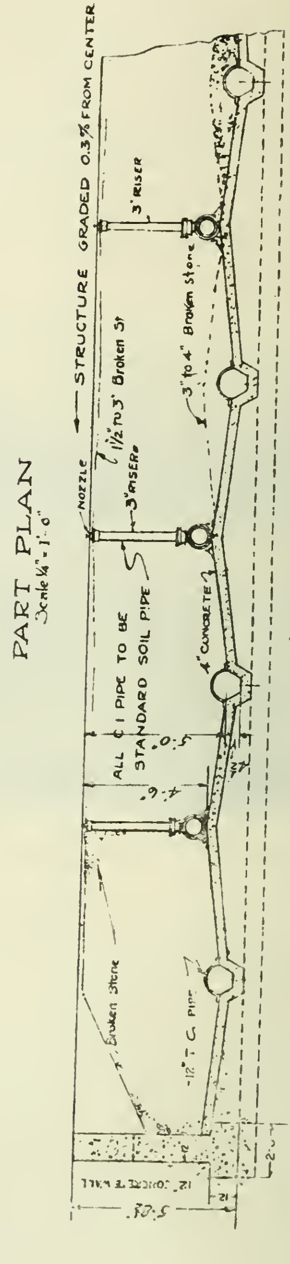


Fig. 6. Longitudinal Section, Standard Trickling Filter

SEWAGE DISPOSAL

The practice of the construction division has been to install plants providing for the partial or thorough treatment of sewage at camps, depending upon local conditions and requirements, where disposal by dilution or connection with a municipal sewerage system was impossible or impracticable. Sewage treatment plants have been constructed at many of the camps and cantonments and at other points, such as housing projects, arsenals, proving grounds, etc. These plants number over 100. They consist of either tank treatment with chlorination of effluent or complete treatment works consisting of tanks, trickling filters, secondary sedimentation tanks, and in some cases chlorination of the final effluent.

Sludge Bed, Fort Sheridan General Hospital No. 28, Sewage Disposal Plant.

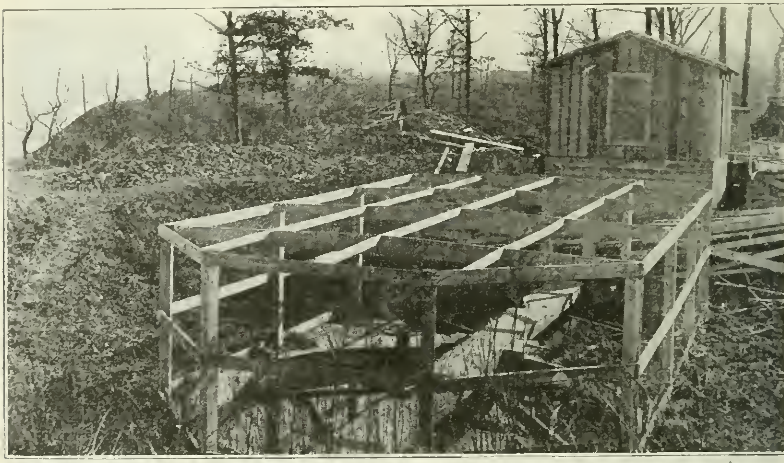
The factors of prime importance in reaching a conclusion as to type of tank to be adopted as a standard were the following: (a) Simplicity of design, to expedite construction; (b) Low cost, because of temporary use; (c) Adaptability, certain characteristics of camp sewage having been assumed.

After giving this matter very careful consideration, it was concluded that a single story tank of a special design most nearly met the requirements. At a later date an advisory board of engineers, appointed by the Council of National Defence, unanimously approved of the design.

The tank may be described as a one-story, multiple-stage digestion tank. It functions differently than other single story continuous flow tanks. Each unit is divided into three or more compartments and are so baffled as to secure the maximum effect in sedimentation. The process of digestion of the retained organic matter in a well "ripened" tank is carried out in a series of stages.

The products of decomposition differ considerably in the different compartments. There is a marked difference in the appearance of the liquid in the several compartments, the effluent from the last compartment being much superior to that from the first compartments.

The tanks are so designed as to admit of great flexibility in operation. It is possible to transfer the sludge from one compartment to any other compartment. This makes it possible to secure very satisfactory digestion of the sludge which accumulates in the first compartment before discharging it upon drying beds. The sludge is removed from the several compartments by means of draw-off pipe lines very similar to the methods used in Dortmund, Travis



Settling tanks and chlorination house, Fort Sheridan General Hospital No. 28, Sewage Disposal Plant.

or Imhoff tanks. It is therefore unnecessary to de-water a tank for the purpose of removing sludge. This feature is a decided improvement on the method of handling sludge in a Cameron septic tank. The baffling is so arranged, and especially at the outlet end of tanks, as to make it possible to avoid the "carrying over" of suspended matter which is so characteristic of the open horizontal flow tanks. As soon as a tank of this type has been "ripened" it will be found that the scum and sludge, especially in the last compartments, give an alkaline reaction.

The effluent from these tanks is of excellent quality for secondary treatment. The suspended matter is, to a large extent, mineralized and adds little to the load on filter. The effluent is in a readily oxidizable condition. This conclusion is reached partly from results of analyses of tank effluent and also from the results obtained in the nitrification and oxidation of the effluent by means of shallow trickling filters.

Unfortunately, the results have not always been as satisfactory as would be indicated by the foregoing description of a normally developed plant, due to the fact that through misuse of the collecting system, large quantities of grease, garbage and paper have been deposited in the tanks. These materials are the most difficult classes of matter to be treated in a plant depending entirely upon biological action. Wide variations in results have been noted between plants of the same design located at camps only a few miles apart. The difference in action is attributed chiefly to the quality of the water. This matter has been given a great deal of consideration and special investigations are being made to establish fully a theory accounting for this phenomenon.

The adoption of a single story, multiple-stage tank has resulted in a great saving in cost of construction. Although it is impossible to give exact figures showing a comparison of cost between this type of tank and the Imhoff tank, it is roughly calculated that the savings due to the adoption of the former tank have been in excess of two million dollars.

The speaker appreciates the fact that there is a wide divergence of opinion regarding methods of sewage treatment, resulting undoubtedly from the fact that there is a great variation in climatic conditions and characteristics of the sewage to be treated, the experience gained in one locality oftentimes being of little value as a criterion for use in another where conditions are radically different.

The two-story or Imhoff tank has been quite widely adopted in this country. It has given reasonably good results where properly installed and very carefully operated. It is a type of tank that requires constant attention. Because of this fact, many of the installations have given unsatisfactory results and many plants have eventually been abandoned. Unless the local conditions are especially favorable, the cost of an Imhoff tank installation would be so high as to be properly termed prohibitive.

TRICKLING FILTERS

The trickling filter was adopted for the secondary treatment of sewage, owing to its large unit capacity, simplicity of operation and low cost of construction, as compared to contact filters or sand beds. The standard type of filter adopted for use at the camps differs considerably from the usual municipal engineering practice in certain details. In 1917, the standard depth of filtering material was 6 feet. In 1918, a depth of 5 feet was adopted. It is the speaker's opinion that a filter of even less depth could be advantageously used, especially in southern latitudes. The filters have been designed on the simplest possible lines, omitting several of the features heretofore considered more or less essential. Wherever practicable, retaining walls have been omitted, the filtering material being terminated with steep slopes.

The rectangular arrangement of spray nozzles was adopted, as it was found by comparison with the diagonal arrangement that the

cost of construction due to the reduction in amount of cast iron pipe required would more than compensate for the slight increase in area necessitated on account of imperfect distribution. The extensive system of under drains was also eliminated. The invert of drains and gutters are in a plane parallel to the spray nozzles. The drains and gutters are of an inclination approximately equal to the average hydraulic gradient of the distributing pipe lines. This not only gives more uniform discharge from the nozzles but greatly simplifies the construction of the filter floor.

The filtering material consists of hard, durable crushed rock or slag, the pieces of which will pass a screen of 2½-inch openings and will be retained on a screen of 1½-inch openings. It is desired to secure relatively coarse rock having little variation in size of

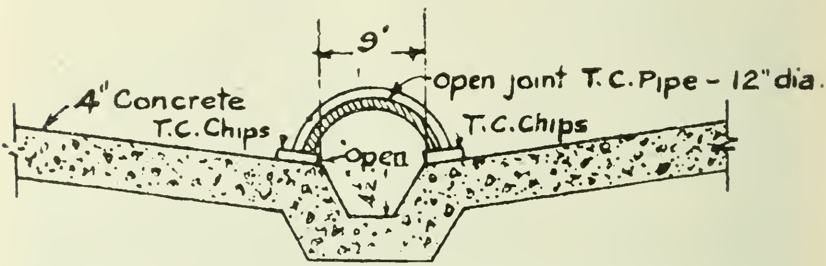


Fig. 7. Typical Section through Gutter, Standard Trickling Filter

pieces, in order that the voids may be large enough to insure a good circulation of air throughout the upper portion of the filter when a thick film has accumulated on the rock surfaces. The most effective rock filter that the speaker has had personal experience with was constructed substantially in accordance with the preceding description. The success of this filter is, to quite an extent, due to the fact that the dosing chamber after the first season of operation was reduced to such an extent that the sprays operated for periods not exceeding two minutes.

The present practice of the construction division is to limit the spraying period to one and one and a half minutes. By this method of operation there is little danger of drenching a relatively shallow well aerated filter bed to such an extent that tank effluent would pass the filter without the proper aerobic action. If the tank effluent discharged upon such a filter is of satisfactory quality, the effluent from the filter should show a very high degree of nitrification.

In the case of a deep filter with a longer spraying period, a considerable amount of the tank effluent immediately percolates to the lower portion of the filter where the air supply is inadequate, with the result that the effluent from the filter is oftentimes unstable. In some cases anaerobic action develops in the lower portion of the filter owing to this condition of operation.

Intermittent sand filters were constructed at two of the Northeastern cantonments. They were expensive plants to construct and to operate. At one plant, where the sand was especially adapted to this purpose, the beds were completely clogged with grease before relief was obtained by the installation of the more effective grease traps. At the other cantonment the sand was less suitable for filters, and as a consequence tank treatment was adopted as an auxiliary and finally a trickling filter was constructed for the secondary treatment.

It is the speaker's firm conviction that greater attention should be paid in the design of plants to securing satisfactory results at a minimum cost and simplicity in operation. Unless the cost of sewage treatment plants is kept low, the number of new plants will be greatly reduced and the advancement of municipal sanitation to that extent retarded.

DISCUSSION.

Langdon Pearse, M. W. S. E.: I was very much interested in this paper and discussion, and in what Major Doten had to say about the sewage disposal plants, as many of the problems which he has had were had at Great Lakes, and he has been fortunate in being able to experiment further and carry on the work further, as apparently there are a great many improvements on the latter equipment he speaks of at Fort Sheridan which have not been installed at Great Lakes. It is especially interesting to note what he said about the sand beds in comparison with the trickling filters, as Great Lakes has established originally a septic tank and roughing and sprinkling filters. The last plant has a septic tank somewhat similar to those he mentioned, excepting that between the preliminary and secondary septic tanks there is a sludge chamber into which all sludge and scum are drawn off. The effluent is taken from the second tank down a set of steps to a dosing chamber. These steps add oxygen

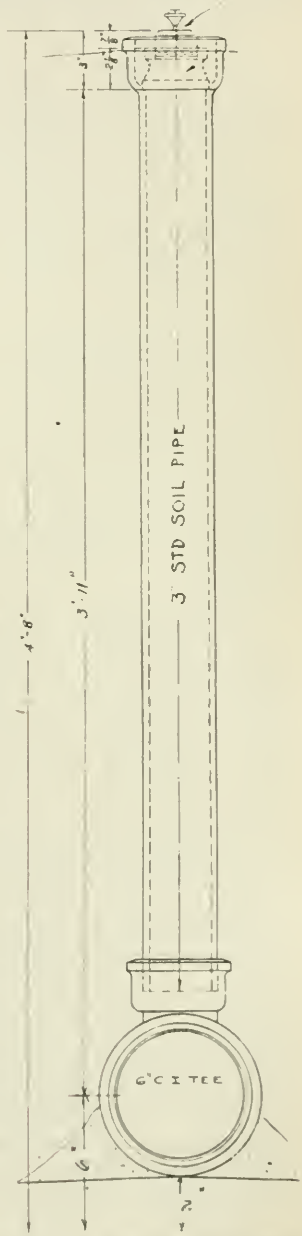


Fig. 8. Details of 3" Riser, Standard Trickling Filter

to the effluent. From there it passes through the dosing chamber into a sediment basin and through a rapid sand filter very similar to the construction of a water filter plant.

The results obtained there have been very good as far as we can carry them. There was considerable trouble with the grease, but this has been reduced by the installation of grease traps, and the elimination or the prevention of the clogging of the filter beds with grease has been taken care of by chlorinating the influent.

In that way the filter beds can be kept clean. Inasmuch as the plant has been worked at considerably over the rated capacity, it has been hard to determine definitely what the plant would actually do under the conditions for which it was constructed. It was also thought that a little different baffling in the sediment basins would increase the amount of suspended matter, as it was found that with the longitudinal baffling there is an ebullition carried on in which the solid matters are being continually raised from the bottom to the top. This is not apparent in the sediment basins when they are perfectly clean, but after a little sediment is deposited in the bottom it is necessary to clean them out.

I would like to ask the Major if in this type of plant he can readily get rid of all the sludge without special sludge chambers. That was very interesting, as at Great Lakes they have the sludge chambers in which the sludge is left for several months before it is removed.

Major Doten: Within a few weeks after a plant is placed in operation the sludge in the second, third and fourth chambers is so well digested as to be readily dryable. The sludge in the first compartment, however, is not in a condition for drying, and it is oftentimes necessary to transfer that sludge by means of the sludge pipe system provided for that purpose to compartments two or three. By lowering the water level in these compartments by means of "drawdown" valves it is possible to transfer the sludge from the first compartment to the other compartments, thereby relieving the first compartment and giving a longer period for the digestion of the sludge thus withdrawn. At the Fort Myer plant we experimented to see how long we could leave the sludge in the first compartment without transferring it to the other compartments. It is now over a year since any was withdrawn from the first compartment. The sludge and scum which have accumulated in this compartment has undergone a change due to hydrolysis, the older portions becoming finely divided. Much of this matter is uplifted by gas action and is carried over the sludge dam by current action into the second compartment. The currents in the first compartment increase in velocity as the cross section diminishes, due to the accumulation of sludge and scum. The action in the second and other compartments is similar to that in the first, except that the velocities are lower.

Mr. Pearse: In that entrance chamber where the sludge enters the sewage plant do you have trouble from offensive odors?

Major Doten: I have never noticed any objectionable odor at any of the other tanks. There is no valid reason for anticipating trouble from odors on account of this feature, as there would be no gas rising from decomposing matter at the bottom of the tank at this point.

Mr. Pearse: We had difficulty that way. We had to cover over the tank to the first baffle. In the first digestion chamber there was no trouble. We never could get the scum in the first entrance chamber, which is five or six feet wide. The action is entirely too violent for the scum to form there, but the odor was very offensive. At that plant there was also considerable hydrogen sulphide formed. It was very offensive and its formation apparently was stopped by planting hay bacteria in the scum of tanks and sludge chambers.

Burton J. Ashley, M. W. S. E.: The major's address certainly was very interesting, made more so perhaps because there appeared elements in a number of designs shown which have been in successful use in England for a good many years. I refer particularly to the filter beds with open rip-rap as retaining walls when such beds must come above the natural surface of the ground. Another instance may be mentioned, namely, reducing the amount of under drainage. It never has seemed to me that there existed the necessity in the designing of filter beds for providing the amount of air space underneath the beds that has been provided in many designs and constructions that have been built in this country. I think Mr. Dibdin in his experiments with slate beds demonstrated very clearly the efficiency and the aid which earth worms and protozoans were in the purifying of tank liquids, for upon emptying his beds it was found that the slates were teeming with earth worms, protozoans and the like, which were found to be very beneficial. The broad surface of Major Doten's filter bed floors cannot but afford as good a working area for further biological reduction of solids as Mr. Dibdin's slate areas do. Therefore, it has always seemed to me that it was desirable to have as broad plain surface to the floors of filter beds as possible consistent with the reasonable amount of under drainage that is necessary.

My friend Mr. Abbott here, who, I understand, is now building one of these plants, tells me that the distance between those under drains is something like eleven feet and some odd inches, which is going farther than I ever dared to, but I am glad to see some one confirming my belief and practice by setting a more extravagant precedent. This practice differs materially from that of the great mass of engineers whose plans have been published widely in technical magazines. So, I say in these two particulars I am very glad to see that the authorities at Washington have broken away from some of these old methods and designs and have adopted methods which seem to be more in line and keeping with economy, and yet affording sufficient efficiency.

There is another feature which I may bring up regarding the

design of sewage treatment plants, and in which particular I differ from many others, and that is with regard to the grade or size of material used in filter beds. I do not see now, and I have never been able to see, the reason for putting a three-inch stone into a filter bed, and wasting the amount of useful space it occupies, when if this space were occupied by a smaller media there would be a greater surface for the aerobic film. I think that no authority I have ever consulted has given any reason why three-inch or even two-inch media was used, other than that it would provide sufficient voids to allow the sprinkled tank effluent to pass freely through the filter. That treated sewage liquids will pass freely through smaller voids without ultimate clogging has been proven over and over again.

Many years ago I was attracted to the experiments of Dr. George Reid, the famous county medical officer of health of Staffordshire, England. At that time (1907 I believe) he said that he had had eighteen years experience, and he is still health officer there. Dr. Reid made some experiments with the size or grade of filtering material in a case at Hanley, where he used ⅛-inch material. He inserted in the beds pans at one foot difference in elevations, at depths of one, two, three and four feet and analyzed the samples collected. He found that nearly all of the nitrification effected took place in the upper one foot of the bed. He got but little effect in filtering farther than a depth of one foot. Those experiments were published widely in England and have been abstracted and published in one authority at least—Moore and Silcock if not others—and are classic. Dr. Reid has defended, or did defend, his position in the matter of using finer material, and I believe the local government boards changed their specifications from the old specifications that required filter beds to be not less than four feet and not more than nine feet in depth. It was the depths of these old English beds that first gave American engineers an example to follow, and they seem to have continued to follow them tenaciously.

I have long differed in that respect to both grade of media and depth of filter with many of the practitioners in this country, and on the strength of Dr. Reid's experience have had faith enough to adopt a finer material than is ordinarily used, and, covering an experience of many years, my observations are such that they would prevent me from departing from the practice. We know that every year, sometimes twice a year, there is a sloughing off of excessive aerobic film that must be reckoned with, to keep the voids of any grade of media open.

The depth of the filter with the fine material I have used has been from two to three feet, but I have not been brave enough yet to use ⅛-inch stuff. The size of filter material I have used for many years will vary from one quarter inch to three quarters and up to one and two inches around the collecting drains. The material has been usually gravel, fine washed gravel, or the next grade of crushed stone above screenings. Oftentimes I have had to re-

screen this material in order to get a good, well graded material. The trouble with gravel is that you have an uneven grading. The evener the grade the better results you get. If you do not have an evenly graded material the voids will fill with smaller particles, and thereby reduce the space.

For the sake of showing the comparison of measured surfaces of different grades of filtering media in one cubic foot of space, I recently made some calculations, using spheres of different diameters as a basis of computations. The balls are supposed to be laid in cannon ball layers so as to produce the minimum voids for that particular grade of material. Following is the result:

Diameter of spheres	Number of spheres in one cu. ft.	Sq. ft. of surface in one cu. ft. of media
3″	98	19.5
2″	334	29
1″	2,679	58
¾″	11,000	76
½″	21,430	116
¼″	171,420	234
⅛″	1,371,380	467

In Taylor & Thompson's "Concrete," it is stated that in one pound of ordinary sand there are 44,300 square feet of surface. If in one cubic foot of sand there are 90 pounds, then there should be 3,987,000 square feet of surface in that cubic foot, and should therefore, in a measure, answer for the high efficiency of sand beds in treating sewage.

We will all agree that the capacity of any material is measured by the extent of surface of that material that will work continuously without clogging and with a sufficient amount of air contact. We will also agree that the lower parts of filters are without the amount of fresh air that should be applied there, consequently the most and best work is done at the surface of filters, where the fresh air is first draw down into the beds. It may be that I am the only man who ever designed a sewage treatment plant that had a chimney in it. I designed one plant in which I wished to set up additional air circulation, and to do so built a filter bed with a chimney at one end of it, where it was connected to the lower drains in such a way that the chimney, having a draft, would draw the air downward through the bed clear to the bottom drains and discharge it through the top of the chimney. It was an experiment but it resulted satisfactorily. The results have proven that it had some efficiency, for in the coldest of weather that chimney, I am told, will throw off a very thin vapor, showing that it is doing its work in drawing the air through that bed. In summer the vapor is invisible. Of course, as some of you may know, I specialize on a particular kind of bed, which is so constructed that the air is brought in from the bottom instead of at the top. That cannot be done readily with beds that are not covered, but the small beds

that I have built in large numbers are so designed and constructed that air is applied through the collecting drains at the bottom and is induced to circulate in the opposite direction to that which the tank effluent flows through. I believe that the application of air to the bottom of a bed is a point in the efficiency of the fine grain bed.

Major Doten: The last speaker has referred to the fact that we would all agree that the capacity of the filter is not measured by its cubical contents, putting it in my own phraseology. Has not that really been quite a common practice—to proportion the filter according to its unit volume, using a volume as its capacity?

Mr. Ashley: By taking the upper foot to be as valuable as the lower foot? That is what Dr. Reid objected to?

Major Doten: I would like to say just one word in regard to this Fort Sheridan plant. Mr. Abbott, who is a member of this society, is supervising the work there, and I wish to compliment him publicly upon the speed at which that work has progressed. I am very much pleased with it. I would like a hear a few words from Mr. Abbott relative to his experiences in carrying on the work.

H. R. Abbott, M. W. S. E.: We have listened to a very valuable and constructive paper here this evening. There is one point in connection with this type of tank that should be brought out especially, and that is the original construction cost. In the deep Imhoff tanks it necessitates very expensive excavation work where the ground water level is high, and it is high in a great many cases. It would mean cave-ins on work to put down the tank to those depths, twenty-eight and thirty-three feet. In the Fort Sheridan work we have been going on with that work right through the winter. The weather has been with us and we have been able to carry our work on throughout the entire winter. We have had very little cold weather and scarcely any frost in the ground, and we have made pretty good progress, a good deal better than we would have made if we had a winter like last winter, and it would have cost us a great deal more money than it has.

Mr. Ashley: May I ask if there is any particular reason for extending those supply mains through your filter beds so deep down in the bed? Why might they not be placed at a higher elevation and in that way reduce the cost slightly of the upright standards which bear the sprinkling heads?

Major Doten: The chief reason was that we thought that the plants might possibly be out of service during cold weather and the pipes would be more apt to freeze and burst. If the distributing pipes were located at the surface of filter, they would either have to rest upon a rather insecure foundation, or else piers would have to be constructed or pipe standards installed to support them. There is very little difference in cost between the two systems.

Mr. Ashley: The type of circular Imhoff tank shown and as usually designed has a sludge chamber of much smaller diameter than the upper part of the tank. I was confronted with a case a

few years ago where I knew water would be reached in building it. The tank and sludge chamber had the same diameter, twenty-four feet, and instead of that shoulder between the upper and lower parts it was designed as a cylinder. We built a shoe, and on the outside of the shoe we put a cutter. We dug down some six or eight feet into the ground and there placed the shoe and commenced building the wall of concrete on it, reinforcing the walls as they were built. We went to the depth we wanted to and found that the shoe cut off the water quite readily, and that a slow running pump would keep the water out from the bottom and did so until the work was completed. I do not know what the conditions are up at Fort Sheridan, but if you are back in those clay hills I believe I would not be afraid of the sand veins or pockets furnishing enough water to keep one from digging or sinking a cylindrical Imhoff tank, even though some water might be encountered.

Chicago Terminal Situation

E. J. Noonan, M. W. S. E.,
Chief Engineer, Chicago Ry. Terminal Commission.

Presented March 17, 1919.

IT is extremely difficult to discuss any large terminal situation, and particularly the Chicago terminal situation, without getting into a discussion of the transportation problem as a whole. Any radical change in railroad operating methods is bound to be reflected on the terminal, and many desirable changes in terminal operations cannot be brought about, at least to their fullest extent, without a more or less radical change in railroad operating methods.

A transportation act performed by a railroad begins with the placing of an empty car at the point where it is to receive its load and terminates with the removal of the empty car from the point where it is unloaded.

Under this definition there would be but two terminals, the point of origin and the point of destination. By reason of the fact, however, that there have been a large number of different railroad companies operating in our country, each separate railroad company must have a terminal at each end of its line, and because of the limitations in the length of engine runs, it is necessary for each railroad to maintain what are called "division terminals" located at the ends of the operating division of the railroad.

A railroad therefore in performing the transportation act may move the car through several of its division terminals, and if the car is destined to a point on another railroad it will move through the primary terminals of the originating railroad and through the primary and one or more of the division terminals of the receiving railroad.

Since movement through any terminal is more or less complicated, dependent upon the size and importance of the terminal, and since movement between terminals over a connecting railroad is a simple direct train movement, it happens that the time which the car spends in the terminal is many times greater than the time which the car spends moving between terminals.

It is thus seen that efficiency of railroad operations as a whole is very much dependent on efficiency in the operation of the terminals.

EFFECT OF COMPETITION.

One of the important contributing factors to the failure of terminal operations to show the same degree of efficiency that has characterized some of the other departments of railroad operation has been the application of the competitive principle to terminal developments and operations.

The railroad systems of our country have been built up on the competitive principle. It was the effort of each railroad company

to place itself so that it would be on a parity with its competitors in terminal developments as well as in other matters.

But the application of such a principle as applied to large centers like Chicago falls of its own weight, since it is obvious that each of the railroads cannot secure, maintain and operate adequate terminal facilities in each and every section or district within metropolitan terminal areas where important freight traffic is to be had. The effort to do so has resulted in complications which have increased the cost of terminal operations and in developments which have retarded or placed obstacles in the way of the logical development of the city.

THE COOPERATIVE PRINCIPLE.

The Chicago Railway Terminal Commission was one of the first bodies of its kind to put forth the argument that "cooperation under public regulation should be substituted for at least that kind or degree of competition in railroad operating methods which is destructive and wasteful." It was argued that this should apply to the whole field of railroading, including terminal facilities and services.

The preliminary report of the Commission submitted in 1915 was in substance an argument for cooperation in railroad operations, particularly as applied to the Chicago terminal situation.

The Commission, because of the way it is constituted, was able to secure a frank discussion of this subject by leading railroad executives and in almost every case these men admitted the decided advantages of cooperative operation. They were, however, either more or less dubious of the practical application of the principle, or else, for obvious reasons, did not feel free to commit themselves on the subject.

With the entry of our country into the European conflict and the necessity of coordinating all our resources in a manner to obtain a maximum of efficiency, it was early seen that it would be necessary to remedy the very serious condition presented in the competitive operation of our railroads.

A sincere effort on the part of the railroads to cooperate on their own initiative was ineffective because of the limitations of existing laws and other conditions. It therefore became necessary for the Government to take over the operation of the railroads during the emergency.

Theoretically, with all restrictions removed, the Government should have been able—so far as existing facilities would permit—to approximate the ideal consolidation of our railroad properties. That this has not been done has been due to many factors, principal of which were the war conditions which had very much disturbed the normal orderly flow of business and traffic.

Nevertheless, out of the temporary control—and in the absence of legislation to the contrary we must assume it is temporary control—has grown a recognition of the desirability of retaining at

least those particular features of cooperative operation that are consistent with private control of railroad properties.

Certainly today the proposition of applying the cooperative principle to the solution of terminal problems is no longer received as visionary or impractical, and the fact that railroad officials are accepting this principle is in evidence.

During the past year or more the Committee on Yards and Terminals of the American Railway Engineering Association has been doing very effective work in the study of the terminal question. In its preliminary report, this Committee states that the "unit operation of railroad terminals in large cities was one of such importance that it could well engross the best efforts and thoughts of the Committee."

This Committee has started to work on this subject in a way that seems to me to be a guarantee that the terminal question, and particularly the possibilities of unification and consolidation of facilities at the larger terminals of the country, will receive the greatest consideration by able railroad engineers and will result in decided advances in the art of terminal operation.

APPLICATION OF A SOLUTION OF THE TERMINAL PROBLEM.

From discussions so far published it would seem that the railroads would emerge from the present governmental control under one of the following forms of management:

A. The management of the entire transportation facilities of the country as a unit, somewhat after the manner the railroads are now being operated.

B. The forming of group managements within natural geographic or traffic divisions or regions with or without a central governing board to facilitate interchange between groups.

C. The return to the original individual managements but with provisions for pooling earnings and expenses—under some form of governmental regulation.

D. The return of the railroads to their individual managements with the pre-war status unchanged.

The alternative treatments of the general transportation problem have been set down above, not in the order of personal preference but in the order most desirable from the terminal standpoint.

The theoretical correct solution of the terminal problem at Chiacgo in its entirety would only be possible under a condition in which the entire railroad system of the country was being operated as a whole under a central management—form A given above—because only under such a condition would it be possible to exercise control over a shipment from point of origin to point of destination.

By exercising control over a shipment from origin to destination it is possible to consolidate and route shipments so that a minmum of delay will be incurred in intermediary terminals, and in


RAILROAD ROUTE AND TERMINAL MAP
CHICAGO
AND VICINITY
Office of Chicago Railway Terminal Commission Feb 1915.
Scale
LAKE MICHIGAN
CHICAGO
SOUTH CHICAGO
INDIANA HARBOR
CITY LIMITS
ILLINOIS
INDIANA

Fig. 1

many instances the shipments may be consolidated and routed so as to entirely avoid large congested terminal areas like Chicago. This of course only applies to commodities which are handled in large volume and particularly to shipments originating in the West and Central West and destined to Atlantic Seaboard points.

Where such traffic could not be routed around the Chicago terminal, it could be consolidated so that it would pass through the terminal in solid cuts with a minimum of delay.

Even with such a method in operation there would still be a vast amount of freight originating in and destined to Chicago which would have to be handled within the terminal district and the proper coordination and interchange of facilities within the terminal district for the handling of this character of freight is a problem of the very greatest importance.

Should the ultimate treatment of our general transportation system take the form of either "B" or "C" outlined above, it would seem that only through the formation of a terminal company or the pooling of all terminal facilities under one management could a solution of the Chicago terminal problem be obtained. Even then, the same theoretical efficiency that would be possible under form "A" could not be obtained.

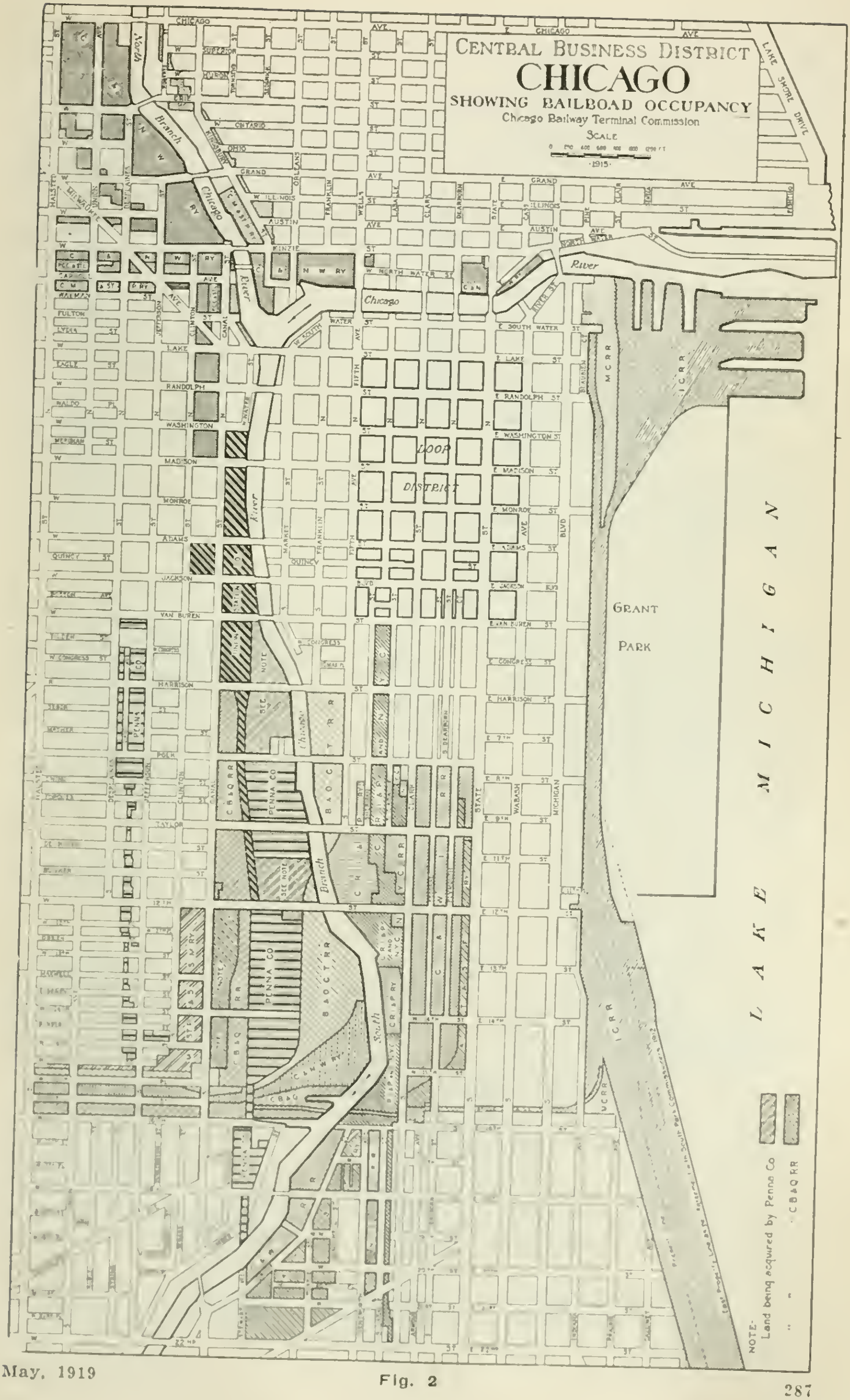
If, however, the formation of such a terminal company or the placing under one management of all terminal facilities were preceded by a thorough study through which a comprehensive operating program were worked out, a close approximation to the ideal could be obtained.

Should the roads be returned to their individual managements on the pre-war status, it is believed that the impetus given to the idea of cooperative terminal operation has been such that the individual railroads will be willing to take advantage of the mutual benefits to be secured in jointly working out terminal developments especially in the more congested districts.

An idea of the magnitude and of the complications in the Chicago terminal district may be had from a study of Plate 1, which is a terminal map of the Chicago district. It will be noted that the railroads approach Chicago from all points of the compass except the Lake Michigan side and that within the district there are terminal facilities from some twenty-six railroads which enter the district and some thirteen railroads which lie wholly within the district.

Within the city limits there are something over 2,700 miles of track, almost 120 individual railroad yards, and within the Chicago terminal district, which includes an area of something greater than the area within the city limits, there are over 4,400 miles of railroad track, and 177 individual railroad freight yards.

During the past few years there has been in operation, at the southwest corner of the terminal area, one of the largest freight yards in the country, and the only yard that acts as a clearing be-



CENTRAL BUSINESS DISTRICT
CHICAGO
SHOWING RAILROAD OCCUPANCY
Chicago Railway Terminal Commission
SCALE
1915
GRANT
PARK
LAKE MICHIGAN
LOOP
DISTRICT
NOTE-
Land being acquired by Penna Co
C B & Q R R

Fig. 2

tween different railroads. Through its operation the interchange of cars between the railroads that use it has been very much simplified.

The clearing yard is reached by both the Indiana Harbor Belt Railroad and the Western Indiana Railroad, over either of which it is possible to reach all of the railroads entering the terminal area.

Inside these two belts the Chicago Junction Railroad acts as a partial belt for handling traffic to and from the stock yards and the manufacturing district.

It is believed that with these facilities and the existing facilities of the individual railroads there is sufficient trackage if properly coordinated and used efficiently under unified operations to meet immediate requirements for handling carload freight.

Future yard developments on the separate lines entering the terminal district should be located along the outer margin of the terminal area and should be planned for an operation that will simplify switching movements and consolidate as much as possible both through freight and freight destined to points within the Chicago terminal.

LESS THAN CARLOAD FREIGHT.

All of the twenty-six railroads which enter the Chicago terminal district maintain facilities for L. C. L. freight, grouped around the central business district of the city, and all located withn an area of approximately two square miles, whereas the city limits include an area of approximately one hundred and ninety square miles. Within this congested area is handled fully ninety per cent of the total L. C. L. freight of all of these railroads. Because of this situation it is the solution of the railroad problem within this area that has received the greatest consideration from the city or civic standpoint.

A greater appreciation of this situation as it affects the city's standpoint may be obtained from Plate 2, which shows railroad occupation of property in the district between Twenty-Second Street and Chicago Avenue and east of Halsted Street.

For convenience of reference this area of railroad occupation is shown on the Plate under different markings as the Northern area, the Northwestern area, the Western area, the Southern area, and the Eastern area.

The Northern area lies contiguous to the North bank of the Chicago River and does not extend more than one city block in width. By reason of the fact that it is necessary to construct city bridges at a certain elevation above the water in the river, railroad property adjacent to the river—provided it is not too wide—does not offer an obstruction to the free flow of street traffic because the streets, in order to meet the levels of the bridges, can pass over these areas without interference with their use for railroad purposes.

The Northwestern area is shown adjacent to the west bank of the North Branch of the Chicago River and extending to Adams Street along the west bank of the South Branch. Because of its

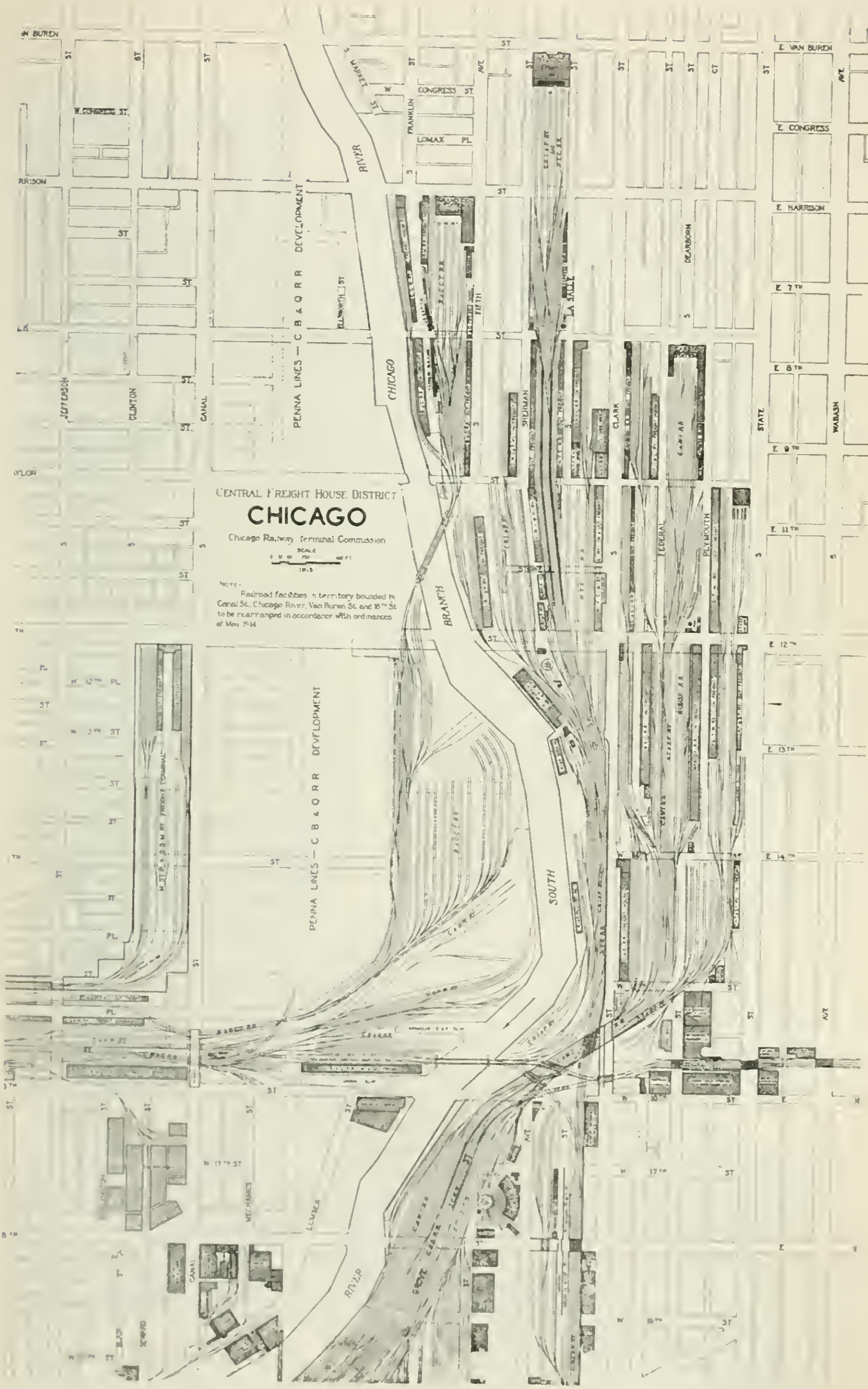

CENTRAL FREIGHT HOUSE DISTRICT
CHICAGO
Chicago Railway Terminal Commission
Note-
Railroad facilities in territory bounded by Canal St., Chicago River, Van Buren St. and 16th St to be rearranged in accordance with ordinances of May 1914
PENNA LINES — C B & Q R R DEVELOPMENT
CHICAGO RIVER
SOUTH BRANCH
E VAN BUREN
E CONGRESS
E HARRISON
E 7TH
E 8TH
E 9TH
E 11TH
E 12TH
E 13TH
E 14TH
W CONGRESS ST
CONGRESS ST
LOMAX PL
FRANKLIN
FIFTH
SHERMAN
LA SALLE
CLARK
DEARBORN
FEDERAL
PLYMOUTH
STATE
WABASH
JEFFERSON
CLINTON
CANAL
MECHANICS
LUMBER
W 17TH ST
W 12TH PL

Fig. 3

geographic position with reference to the City plan, the occupation of this territory with railroad facilities is not seriously hampering the growth of the city.

The Western area, extending contiguous to the west bank of the South Branch of the Chicago River and south of Adams Street, is occupied by a group of railroads which have their terminal facilities in the West Side Union Station. Within this area there are now being constructed modern facilities for the handling of L. C. L. freight in a manner that does not interfere with the extension of all east and west streets through the district and with ample driveway spaces, in addition to the City streets, will reduce to a minimum congestion around the terminal district.

The Eastern area is shown as all of that land occupied for railroad purposes between Michigan Avenue and Lake Michigan. Because of its location the occupation of this area with terminal facilities does not interfere with the expansion of the central business district or with the flow of traffic to and from the central district.

The Southern area is that area occupied by railroads between State Street and the South Branch of the Chicago River, its northern limits being an irregular line extending in one place as far north as Van Buren Street.

In this area besides the Grand Central, LaSalle Street, and Dearborn Street passenger stations are located the freight houses and team track facilities of the Santa Fe, Grand Trunk, Wabash, Chicago and Eastern Illinois, Monon, Erie, New York Central, Nickel Plate, Rock Island, Baltimore and Ohio, Pere Marquette, and Chicago Great Western Railroads.

The existence of this large terminal area immediately contiguous to the congested central business district of the city, particularly with the present character of occupation, is a serious obstacle to the natural development of the city in a southerly direction and adds greatly to the street traffic congestion.

It will be seen by reference to Plate 3 that north of Van Buren Street there are nine north and south streets, while extending to the south are only four, from one of which, Michigan Boulevard, heavy traffic vehicles are excluded, and another, Clark Street, is narrowed at points and of an undulating grade, which restricts its use for through heavy vehicular traffic.

All of the railroad freight houses in this area are of an antiquated type, have practically reached a point where their reconstruction is required in order to afford increased shipping facilities and their operation and construction is such as to cause a maximum of congestion on the streets leading through and to this area.

The present railroad facilities in this southern area are shown on Plate 3. Notice how the LaSalle Street Station projects beyond the rest of the area with the corresponding detrimental effect on property devlopment on either side.

Another thing which impresses one in observing the railroad facilities in this area as shown by this plate is the small area occu-

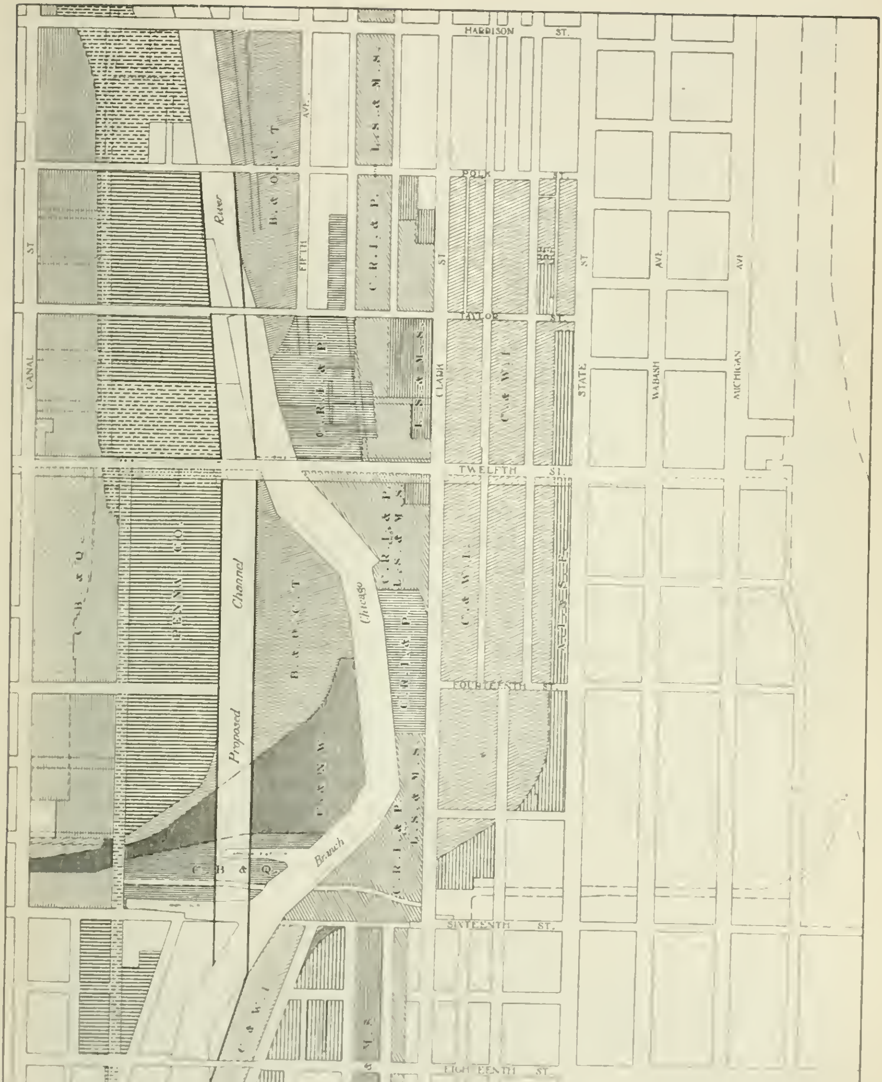

HARRISON ST.
POLK ST.
TAYLOR ST.
TWELFTH ST.
FOURTEENTH ST.
SIXTEENTH ST.
EIGHTEENTH ST.
CANAL ST
FIFTH AVE.
CLARK ST
STATE ST
WABASH AVE.
MICHIGAN AVE.
ARCHER AVE.
River
Chicago
Branch
South
Proposed
Channel
PENNA. CO.
C. B. & Q.
B. & O. C. T.
C. R. I. & P.
L. S. & M. S.
C. & W. I.
C. & N. W.
STRAIGHTENING SOUTH BR. CHICAGO RIVER
SHOWING ADJACENT PROPERTY

Fig. 4

pied by buildings as compared with the great area occupied by tracks. This emphasizes the necessity for a more intensive use of this valuable real estate. The absence of through streets previously mentioned is again shown on this plate and it can be readily appreciated how the use of this property for less-than-carload freight with the present character of facilities leads to congestion on the City streets leading into this area.

Public interests, shipping interests and economy in railroad operation demand that this entire terminal area be revamped and modern freight house facilities be constructed that will provide adequate shipping facilities that can be operated without undue congestion on the City streets. Such a development would result in a saving in operating costs to the railroads and a utilization of property now superficially occupied.

To bring this about it is necessary for the facilities to be constructed and operated along cooperative lines, in fact, it is practically impossible otherwise to bring about the improvement that is necessary in this area.

Where a large area—such as the southern area—interferes with the extension of the City streets, it is necessary—in order that railroad operation be not totally restricted—that the streets be extended through this area on viaducts. In Chicago the existence of river bridges fixes the plane of the elevation of these viaducts at such a level that it is possible to operate trains underneath without making excavations so deep as to require sub-drainage facilities.

The two-level type of freight house fits in admirably with a condition where it is necessary to extend city streets on viaducts over railroad property, and makes possible more intensive use of valuable real estate in that the lower level can be occupied with tracks while the level immediately above can be occupied by freight houses, buildings and driveways, and in the development of the Southern area, it is essential that some type of two-level freight house should be adopted.

RIVER STRAIGHTENING.

The South branch of the Chicago River—which forms the western boundary of the Southern terminal area—makes a decided bend to the east, so much so that whereas at Polk Street the distance from Clark Street to the river is 1,150 feet, at Fourteenth Street it is only 150 feet.

This has the effect of cramping the approach to that portion of the Southern area lying west of Clark Street. This same bend gives a shape to the portion of the western area immediately adjacent to the river that prevents its being developed along logical lines.

The situation is such that great benefit could be derived—both by the holders of railroad property and the public—if the river between Polk Street and Sixteenth Street were straightened so as

to have a direction as nearly as possible parallel with the north and south streets.

There are no engineering or physical difficulties in the way of straightening the river and the work could be accomplished at a very reasonable cost.

The benefits to be derived through river straightening are so apparent that the Railway Terminal Commission—ever since its organization—has been endeavoring to bring about a situation that would permit of this improvement being made.

Agreements have been secured from railroad holders of all of the property abutting on the west bank of the river with the exception of the property held by the Chicago & Northwestern Railroad.

On the east side agreements have been secured from the B. & O. C. T. and from the Chicago and Western Indiana, but the principal portion of the frontage abutting on the eastern bank is owned by the New York Central and C. R. I. & P., with which companies no agreements have as yet been entered into.

The agreements with the other railroads establish a tentative line to which the river may be straightened and also provide for a method of arbitration for determining benefits and damages accruing from the river straightening.

Plate 4 shows this tentative line of river straightening and also shows the ownership of the property abutting on the river channel.

It will be seen by reference to this map that if the river were straightened along the line indicated there would be a substantial transfer of property from the west side to the east side of the river and a gain in the total net area of property due to the direct course of the river of about 200,000 square feet.

The property in the territory adjacent to the proposed river change has a value varying from $5.00 to $20.00 per square foot and a reasonable value placed on the net increase in area noted above of 200,000 square feet would represent a figure sufficient in itself to cover the entire cost of making the physical improvement.

The difficulty that has stood in the way of the accomplishment of this improvement has been very largely due to the fact that after river straightening, the property that would be transferred from the west side to the east side of the river—as well as the old bed of the river—would have to be resubdivided or an adjustment made in property lines before the full benefit of the improvement could be realized, and the effort has been made to secure a cooperative action between the interested railroad companies that would make possible either this adjustment or a cooperative development of terminal facilities in the areas affected by river straightening.

To make such a thing possible it would be necessary for the interested railroads to work out a plan of development that would be satisfactory to all, and while the railroads have shown a willingness to give consideration to this subject, no tangible results have been accomplished.

The straightening of the Chicago River should be the first step

Areas in Square Feet Affected by Chicago River Straightening on the Assumption that Old River Channel Would Revert to Abutting Property

Railroad	Area Before Channel Change	Area From Old River	Area for New Channel	Increased by Change	Decreased by Change	Total After Channel Change
B. & O. C. T. R R.	1,299,060	202,150	408,160	......	206,010	1,093,050
C. & N. W. Ry.	499,000	117,700	70,500	47,200	......	546,200
C., R. I. & P Ry.	665,747	152,720	......	152,720	......	818,467
L. S. & M. S. Ry.	220,347	......	......	......	......	220,347
C., R. I. & P. and L. S. & M. S.	1,098,628	261,360	......	261,360	......	1,359,988
C., B. & Q. R. R.	130,230	40,000	58,200	......	18,200	112,030
C. B. & Q. R. R and C. & N. W.	8,970	3,560	7,200	......	3,640	5,330
Pennsylvania Co.	85,035	13,200	85,035	......	71,835	13,200
St. C. A. L.	19,741	4,590	......	4,590	......	24,331
Armour Slip	32,200	17,000	9,670	7,330	......	39,530
Union Slip	19,000	3,470	18,805	......	15,335	3,665
Present River	......	193,280	193,280	......	......	......
Totals	4,077,958	1,009,030	850,850	473,200	315,020	4,236,138

524,950 Area new River 12th to 16th
325,900 Area new River 12th to Polk

850,850 Total—No streets

*719,075 Area old River 12th to 16th
341,155 Area old River 12th to Polk

1,060,230 Total

1,060,230 Total old River
850,850 Total new River

*209,380 Difference

194,125 gain in area 12th to 16th
15,255 gain in area 12th to Polk

*209,380 Total land gain sq. ft.

*Includes Armour and Union Slips as part of River.

taken towards the solution of the terminal problem as it affects this Southern area and any logical plans for the development of this territory must be predicated on a straightened Chicago River and should be further predicated on a unified or cooperative development that would make possible the elimination of all existing railroad property lines and the relocation of facilities, in a sequence that would be in harmony with the order of entrance of the several railroads into this territory.

As many as possible of the through streets should be extended through this territory.

As far as studies have advanced on this subject at the present time there seems to be no reason why all of the north and south streets in the loop district—with the exception of Market Street—should not be extended through the area continuously south to Archer Avenue.

In the matter of the relief of street congestion there is practically no other improvement that would be so great an accomplishment, and this could be brought about without in any way detracting from the availability of this territory for railroad purposes, provided the improvement is undertaken with the object in view of unified operation of the railroad terminals.

Under this plan it would be possible to increase the capacity of the railway terminals in this area at least three times without increasing the area occupied by railroad property and at the same time open up the territory so that there would be an easy flow of street traffic through its entire length.

The average value of the property in this territory is about $20.00 per square foot while the reproduction cost of all of the facilities in this territory—exclusive of passenger stations—would not exceed $2.00 per square foot. This indicates a very uneconomical use of property.

There is no reason why—with the development of the two-level plan—all of this property—exclusive of streets—should not be covered with buildings adaptable to warehouse or light manufacturing purposes and in this way a revenue secured which would leave the actual facilities used by the railroads free of interest charges.

Under the present situation with the superficial operation of property, there is required on an average an area of 2,000 square feet per car standing capacity. If this property is worth $20.00 per square foot, with interest at 5%, it represents an interest toll of about $1.00 on every ton of freight handled through this terminal.

PLAN OF DEVELOPMENT.

For obvious reasons no detailed drawings have been prepared for the railroad development in this territory, but as illustrative of the possibilities a tentative plan was included in the 1915 Report of the Railway Terminal Commission. This plan is based on a two-level station with cross platforms on the

street level and with warehouse space above. The cross platform idea contemplates the freight houses at the team levels being at right angles to tracks which would be on the lower level divided by longitudinal platforms.

This plan has decided advantages in that it permits of development of the areas so as to provide a maximum of teaming space and a maximum of track space with a minimum of street congestion. Whether or not it is the best plan in a given situation would depend entirely on detailed study of comparative designs. It is submitted in this paper merely as showing one of the possibilities, and in order to illustrate what is meant by intensive development.

This plan shows a development for freight house purposes occupying only the territory between Clark Street and the straightened Chicago River and extending from Taylor Street to Sixteenth Street and yet it shows a car standing capacity of three times the car standing capacity of all of the railroads now having freight house facilities in this southern terminal area.

PASSENGER STATIONS.

While the question of the revamping of freight facilities in this southern area has not passed beyond the discussion stage, it is believed that real progress has been made towards the solution of the passenger terminal problem.

Back in 1893, the group of railroads occupying the West Side Union Station made application to the City for an Ordinance providing for the construction of a new passenger terminal. This immediately raised the question as to the policy to be pursued by the Railway Terminal Committee of the City Council, a Committee which had been recently constituted one of the standing committees of the City Council.

The Railway Terminal Committee immediately started a series of public hearings for the purpose of having the fullest possible discussion on this subject.

The result was that the Committee was flooded with a vast amount of immature plans and suggestions, the value of which it was unable to determine. In order to secure advice on this subject the Committee retained Mr. John F. Wallace to make a study of the terminal situation and advise the Committee as to what its position should be with reference to the location of the Union Passenger Station at Canal and Adams Streets.

The result of Mr. Wallace's study was summarized in a report made to the Committee in which he recommended that a west side Union Station be located between Adams and Jackson, along the river, and that all of the railroads which could not logically use this station be concentrated in a new station which should be constructed on the lands of the Illinois Central Railroad, adjacent to Twelfth Street and the Lake Front. The result of this plan would be the ultimate removal of the Dearborn, LaSalle Street and Grand Central stations.

The primary consideration for this conclusion was that such an arrangement would make possible the providing of adequate passenger station facilities without interference with the development of the city southward or westward.

The site selected for the West Side Union Station was adjacent to the Chicago River, and in this location it was possible to develop the station and facilities in a manner that would permit of all of the east and west streets passing over the station development, and in this way would not interfere at all with free flow of traffic into the Central District.

The other location for the South Side Railroads on the territory of the Illinois Central Railroad would put this station east of the easternmost street reaching to the Central District from the south, and therefore the location of facilities in this location would not interfere with the flow of street traffic.

It was his opinion that after the removal of the passenger stations, freight facilities could be created in the territory occupied by the railroads along the southern edge of the Business District in a manner that would permit of streets being passed through the district.

About the time that Mr. Wallace made his report to the Committee a group of citizens employed Mr. Bion J. Arnold to make a report on the terminal situation and review the findings contained in Mr. Wallace's report.

Mr. Arnold concurred with Mr. Wallace in the desirability of the two locations for passenger terminals but thought that the West Side Union Station would better be located at Harrison Street instead of Adams Street.

After the passage of the Union Station Ordinance the City Council created the Chicago Railway Terminal Commission, its personnel made up of: John F. Wallace, as chairman, and including Bion J. Arnold, Walter L. Fisher, who had acted as counsel for the Citizens' Committee during the negotiations for the West Side Terminal, Mr. E. H. Bennett, consulting architect to the Chicago Plan commission, the Corporation Counsel, the Commissioner of Public Works and the Chairman of the Railway Terminal Committee of the City Council.

In 1915 the Commission made a preliminary report, in which it concurred with the previous recommendations of Mr. Wallace and Mr. Arnold for three passenger terminal stations.

Regardless of any changes or consolidations of entrance routes for passenger trains, the three station plan, i. e., the Northwestern Station, the West Side Union Station, and the Twelfth Street Illinois Central Station, seems to be the most desirable ultimate passenger station arrangement for Chicago. With the widening and improvement of Canal Street and the double level extension to the North Side, which is part of the West Side Union Station Plan, and the widening and improvement of Twelfth Street now under way, there will be facilities for the free flow of vehicular traffic

between the stations, around the congested Loop District, and by the same arrangement these three stations will be readily accessible for vehicular traffic from all sections of the city. Contemplated plans place these stations equally acessible with improved rapid transit and street car transportation.

The work on the West Side Side Station has been very much delayed on account of the war, but recently authority was received to proceed with this work and the present plans contemplate carrying this work to completion with the greatest possible speed.

During the past year and a half negotiations have been carried on with the Illinois Central Railroad Company and at the present time these negotiations have advanced to such a stage that a tentative ordinance has been prepared which is practically in a shape that is acceptable to all parties concerned, and there seems to be no good reason why this ordinance should not be passed within the next few months.

This ordinance would provide for the construction of a new passenger terminal fronting on Twelfth Street extended east from Michigan Avenue, with a capacity of at least twenty-six tracks in the initial development and the possibility of a future lower level development of the same number of tracks. A station of this size would have a capacity sufficient to accommodate all of the through passenger trains of the railroads now occupying the three passenger stations on the South Side, west of State Street.

A very popular interest has been taken in the project of the Illinois Central Railway Company because this improvement will carry with it a settlement of the Lake Front question and make possible the improvement of the Lake Shore, with parkways, driveways, bathing beaches, etc.

The West Side Union Station project, with the freight development connected therewith, and the Illinois Central Lake Front project, are each monumental in character and will involve a great deal of engineering detail. It would require a separate paper to adequately describe each project.

CONCLUSION.

It has been the effort to limit the discussion in this paper to general problems because the solution of these general problems must precede a consideration of details.

The limitation of space, however, has prevented even the presentation of all the general problems affecting a solution of the Chicago terminal situation. Many of these are operating problems and are dependent more or less on the eventual railroad policy. Particularly is this true in the handling of less-than-carload freight.

Chicago is a commercial city of first magnitude, and its business has been built up largely on the service rendered by the railroads, a service that has frequently been performed at a high cost. There are great possibilities in the reducing of this cost through consolidation of shipments where a similar service is rendered

between important points by several railroads and through the more extended application of the sailing day principle. The more extended use of universal freight receiving stations would be of unbounded value to the shipping public in the reduction of drayage charges and to the city in the reduction of street traffic congestion. As the motor truck supersedes the horse-drawn truck the value of reduction in traffic congestion will become more and more important.

Through a greater use of the tunnel system, and the coordinating of it as part of our facilities for handling less-than-carload freight, it should be possible to make the operation of universal receiving stations reflect an ultimate profit to the railroads,

The solution of the passenger station problem as outlined herein is based on the assumption that eventually the through passenger stations recommended will be used exclusively for the accommodation of through passenger trains and that other terminal facilities will be provided for suburban trains. These facilities should take the form of continuous tracks with unloading platforms and should permit the connecting up of the suburban service of all the railroads in a way that would permit the through routing of the balanced portion of the traffic and the interchange of coach yard facilities.

DISCUSSION.

J. R. Bibbins, M. W. S. E.: Although we often travel daily on the transportation systems of Chicago, we can know very little about the complexity of railroading inside of our two hundred square miles of city. One authority on railroads has stated that, if the full capacity of main line track could be used without having delays imposed upon the movement of traffic at various points upon the line, only one-tenth of the railroad mileage in the United States would be necessary. That may very likely be true, as it means ten to one in terminal mileage. The point is, of course, that the terminal is a reservoir, and wherever main line traffic is retarded you must provide the reservoir; the slower it moves, the more the reservoir must be expanded. As the city terminal is the final destination or transshipment point, city terminals have necessarily spread out broadly and taken far more land than perhaps seems necessary at the present time. We should not forget the fact that these terminal areas were acquired long years ago when land was cheap and often when it was as a concession to the railroads for establishing their service. They could not be obtained now at reasonable cost.

Until I had an opportunity to study the traffic of some of the ports of the United States and the tremendously important function of warehousing, I never fully realized how important warehousing was in this "land port" of Chicago. The point, of course, is that the jobbers use Chicago as a storage reservoir for commodities bought at certain times of the year and held over until they can be retailed to better advantage. So, as the author says, a great

mass of freight is sent to Chicago, stored and shipped out again, over the same platform and the same tracks. This has fostered the growth of the Central Manufacturing District of Chicago. Business has grown and thrived on the so-called "store door delivery" which was introduced at a time when it was considered to be a desirable means of promoting the freight business. As the situation developed there were those who considered that it introduced an element of discrimination, and became the subject of serious investigation. So, as time goes on, the situation changes with point of view. We think we are on solid ground; then some new condition arises and the entire terminal plan requires reorganization. The element of chance cannot be avoided in progressive times.

In speaking of the transit delays, I recall that the average demurrage time on freight cars in Chicago is about 3.5 days; in a more recent survey at the terminal port of New Orleans as high as eight days. Set this against the car shortage occurring at certain seasons, and particularly when marine service is disturbed, and you will see how vastly important the terminal situation becomes. In fact, it has become so important that a new society of terminal engineers has been organized.

Regarding the straightening of the Chicago River, it ought not to be so difficult when the net profits in land rearrangement are so clear. Cleveland has a similar problem in the Cuyahoga River, which wriggles and turns so much as to produce a water front distance several times the air line distance. Yet the situation is entirely different from Chicago, as there will be very little if any profit for the city or the railroads by the change only to shipping and wharfage. But Cleveland proposes to carry its plan through. Chicago can hardly do less, with black instead of red figures on the final balance sheet. How many Chicagoans realize that Clark Street, State Street and Wabash Avenue are the only three through streets east of the river, as Mr. Noonan has already mentioned, and further that only half of Clark Street is really available for city traffic. There is no roadway on the west side of the car line for some distance due to railroad encroachment and the river bend.

You, of course, are familiar with the Sixteenth Street grade separation. At the time it was proposed it was looked upon as an engineering feat; but now we think of it more as a terminal monstrosity. In spite of this one of the features of the original Union Station ordinance, as proposed in 1913, but fortunately withdrawn by the companies, was the construction of a freight line west of the present railroad properties along Canal Street, in which there was a grade separation near Sixteenth Street of five levels, the highest some fifty feet in the air. This shows how a "round table" discussion between the railroads, the city and the engineers can often smooth out difficulties. Instead of those five levels at the Chicago River and Sixteenth Street we have the very desirable plan outlined.

I will now refer to an important matter which leads one into

endless avenues of contemplation, but seemingly no action. In New Orleans I find a widespread belief that the "Lakes to the Gulf" deep waterway is soon to be an accomplished fact. Few realized that for a ship to come from Lake Michigan and land even at the south end of the Drainage Canal it would have to pass through 22 bridges, and that all of the North and West side street traffic of Chicago would be interrupted by each and every vessel. This brings up the question of fixed bridges and the ultimate placement of the "harbor of Chicago," which is deeply interwoven with the terminal system. The Railroad Administration in its report of last year mentioned the fact that very little result had come from the working of the internal waterways of the United States—even the very expensive New York Barge Canal. Why? No terminals, consequently, no barges, no sailing days, no routes, no feeders, only "tramp" traffic. The situation is exactly the same with the Mississippi River, except for the fact that the people of the Mississippi Valley are awakening to the danger of having this whole waterway proposition killed through inaction. They invaded Washington five hundred strong, and after encountering endless delays and shiftings of jurisdiction, they actually secured through the Railroad Administration the right to develop high power barge lines on the Mississippi and tributaries and, most important, obtained through water-rail rates to New Orleans within a territory extending from Gary, Ind., to the Dakotas, and south to the Missouri and Ohio rivers. This simply shows the tendency of the times and the result of real effort. The rates are from one-quarter to one-half lower than by all rail.

What is Chicago going to do about it? Allow the Mississippi Valley, with its tremendously valuable water trunk lines to remain undeveloped? It will so remain until Illinois provides proper facilities at this end. Where will the terminals be located for barge, rail and lake? Where should a new channel cut through? These are extremely vital features of the terminal problem which unfortunately receive very little concerted study. While great progress has been made in planning railroad terminal facilities, yet the real heart of the problem has hardly been touched, and until those waterways which have been provided by Nature are made use of, to create a cheaper method of transportation of bulk products, which should logically have low rates, the Mississippi watershed will remain as when discovered by the intrepid explorers of centuries past.

Finally, there is another neglected element of transportation here in Chicago. There are sixty-five miles of freight tunnel under the streets of Chicago. This tunnel is being used to some advantage, but far below its full possibilities. One wonders what are the causes which prevent its being used more. If we review the newspaper files of the time when that freight tunnel was promoted, I presume we will find some very glowing accounts of the wonderful possibilities of this freight tunnel for Chicago. Now

why is it? At the time the Union Station terminal project was under discussion in 1913 there was some discussion of how the freight tunnel could be used more effectively for L. C. L., transfer and delivery service, and it seemed to be necessary to connect the tunnel with a central L. C. L. clearing yard to render it most efficient for its particular purpose. That has never developed, and there are arguments both for and against it. At the same time, that important investment lies relatively idle under the streets of Chicago, and it ought to be used to greater advantage, as Mr. Noonan has said, in connection with "universal freight stations." Go and inspect one of these stations and you will see what a tremendous saving in street traffic in the city of Chicago could be brought about by the intensive use of this tunnel. It will carry at least seventy-five per cent of the L. C. L. freight. The largest packages of course it cannot carry as the bore is too small. But the fact remains that Chicago is too wasteful of her advantages. Her resources are enormous. They should be developed, not only for her own but for the good or other communities and districts economically dependent upon her initiative. Inertia is neither an asset nor a liability: it is a dead loss.

R. H. Ford: I would like to ask Mr. Noonan if the Chicago Plan Commission considered the clearance of the Twelfth Street viaduct over the railroad yards in their proposed terminal arrangements.

Mr. Noonan: No—and yes. The Twelfth Street improvement and the plans for that improvement were made before the commission got into this problem. The only changes that possibly would be made in it, if it were done over again, from our standpoint would be that it would not be as high as it is. In other words, the Twelfth Street viaduct at present is constructed so as to give a clearance over the tracks of the railroads at the grades they now occupy, which results in an elevation of something like thirty-five feet above city datum. All of the studies that have been made have shown that it is possible to build the city bridges on an elevation of about twenty-five or twenty-six feet. Had that Twelfth Street viaduct been planned as part of an entire revamping of that area, it undoubtedly would be kept at a lower level.

Mr. Ford: Am I correct in stating that the theory of the Chicago Plan Commission is predicated on pushing all east side terminals beyond Twelfth Street?

Mr. Noonan: I am glad that you raise that point. When Mr. Wallace came here in 1913 practically every solution that had been put forward for the solving of the passenger station problem had been based on the building of either one large or a series of several smaller unit passenger stations fronting on Twelfth Street. Mr. Wallace said—and I thoroughly agree with him, and the more I study it the more I agree with him—that it would have been one of the worst things that could ever have happened to the City of Chicago, and that is the very reason why Mr. Wallace recommended the lake front location so as to be able to open up that "neck

of the bottle," because you can make freight developments there that will not interfere with the through streets.

Mr. Ford: I am thoroughly in sympathy with the principles on which the Chicago Plan Commission are working and they are doing a great work, but I cannot understand some of their conclusions. I think we all listen from time to time to a good deal concerning the question of coöperation, but when it comes to railroad terminals, as a rule it seems to me that the plan usually adopted is based upon the principle of first find out what the railroads want and then hold off giving anything to them until they will agree to whatever plan has been outlined by the local bodies through which their lines operate. This often results in expenditures that are not essential in the development of either the community or the railroad as a transportation factor. The time is not far distant in this country when terminal transportation will be recognized by people generally as national problems and not purely local problems; and the best results, for all concerned, will be reached when each part is considered as part of a coöperative scheme in the interest of the state and country at large, as well as the community. These terminal matters are no more engineering problems than problems of transportation. Chicago has been developed by the railroads and is the greatest railroad center in the world. There is no railroad problem in the United States that a counterpart cannot be found in Chicago. With forty-three operating railroads entering the city from every direction, except the east, it possesses problems of freight and passenger transportation combined with municipal (and to some extent river) traffic, that is without parallel anywhere. The solution of these are both interesting and fascinating and they are so interlocked that any one-sided conclusion must more or less affect the others.

To properly consider the Chicago or any other terminal railroad problem, an intimate knowledge of street traffic is, of course, primarily necessary as well as the best and most modern methods to provide for its future, whether it be by separating vehicular, pedestrian, surface car or other traffic from the mail, baggage, team and other traffic originated by the railroads, or separating through and suburban railroad passenger traffic and through and local freight traffic, etc. These are merely factors in the entire problem. Transportation ordinarily considered in railroad parlance is different from transportation usually considered in municipal effort and this causes a great deal of difficulty and is a fruitful cause for delay and friction. An intimate knowledge of railroad transportation and operating methods in its relation to railroad terminals is usually not found with the average citizen who undertakes to work out a solution of such problems. An almost complete failure to look upon the expenditure as a joint affair for the benefit of the state, municipality, as well as for the railroad, is another source of trouble, causing irritation and lack of sympathetic co-operation. On the other hand the railroad man often fails to understand the importance of considering railroad problems from the purely local

standpoint of the community. This is not due as much to indifference as from the constant irritation that comes to railroad men generally by the insistence of communities for re-arrangements, that would not only bankrupt the railroad but would serve no useful purpose from the transportation standpoint.

Chicago is the gateway between the east and the west and any solution must be more than local, because it affects state and interstate traffic as well as purely municipal, state and national transportation problems.

Mr. Noonan: Mr. Ford has raised two or three points, and some of them are points that were raised by Mr. Bibbens. In the first place, the Chicago Plan Commission and the Railway Terminal Commission are two distinctly different bodies. The Chicago Plan Commission has a representative on the Railway Terminal Commission, primarily so because he is supposed to be an expert in certain features. We get the benefit of his assistance on those particular things, but since the Railway Terminal Commission has been created, it has worked in entire harmony with the Chicago Plan Commission, and the Plan Commission has not promulgated any plan of improvement that would be in conflict with the things which the Railroad Terminal Commission is trying to work out.

With regard to the river. About a year ago I was talking to a publicity man employed by the Chamber of Commerce of the United States. He told me he was going to take up this question of internal waterways, and gave me the list of a number of men who had been prominently identified with the internal waterways question, and he said at the time that he was going to talk to those men. I told him that to my notion there were two reasons why we had not made any progress on our internal waterway project. The first of them was because all of the agitation that had been carried on by proponents for internal waterways had been carried on with the idea that they should be used in conflict with the railroads. I told him that was fundamentally wrong; that if the internal waterways were developed they were to be developed as part of the transportation system; they would have to be coördinated; one would have to supplement the other. The second reason was, they had talked too much deep waterway. I do not believe in deep waterways. I think it is wrong as I do not believe we need deep waterways. We want shallow waterways. I think one reason why the Lakes to the Gulf Waterway has been delayed is because for a good many years we have talked deep waterways. If you get back to shallow waterways, to moving stuff in barges, and you get away from the necessity of having movable bridges over the river, the barges can pass under them.

Mr. Ford: Do I understand you to say that you are in favor of fixed bridges over the streets?

Mr. Noonan: Yes. When Mr. Wallace came out here about six years ago he recommended the covering over of the river, just as you did. He said you could not do away with it, because the

river is one of our big factors in drainage here, and we have to pass a certain amount of water through that channel in order to dilute our sewage. We must maintain it for that purpose. If you can use it for barges and lighterage then you are making two uses out of the same facility. I do not see where the Railway Terminal Commission has put forward anything that has been at all detrimental to the railroads. It is not our purpose. Our purpose is to assist the railroads. Railroads are necessary to Chicago. Just as I have said, though, they could not coöperate because of existing laws; they could not coöperate if they wanted to. I believe that everybody realizes that, and that no matter what solution is made of the railroad problem, it will be equipped with the ability to coöperate where such coöperation is advantageous, and even without that the railroads have shown a real desire to coöperate in the solution of this downtown problem.

On this question of river straightening before we got into the war it had progressed so far that the representatives of the Baltimore and Ohio, Chicago Terminal, the Rock Island and the New York Central had agreed to appoint a body of their own engineers to make a study and a recommendation on this problem with a view of seeing if the three railroads interested in that property could not get together among themselves coöperatively to work out this problem. I believe if we had not got into the war they would have gotten something out of it. The only way you make progress is by compromises, and one of the compromises would be the straightening of the river,—the recognizing that the river is there and we have to meet it, and we did not preclude the possibility of any other usage out of it by straightening it. We favored it. I believe that the straightening of the river will come. I believe that it will come regardless of the attitude of the railroads in the matter. Only today I had a conversation along the lines of the possibilities of the Board of Local Improvements of the City of Chicago straightening the river. I believe they could get legislation that would permit them to do it as a street improvement. It may be that is the way to do it. It will involve an initial expenditure on the part of the city, but I think it can get it back.

Mr. Penfield: I was much interested in the talk. I think both the Chicago Plan Commission and the Chicago Railway Terminal Commission performed a very valuable service to the public in that the Chicago Plan Commission have crystallized public attention on certain definite plans, that the city is working along certain policies in its development. The same thing is true of the Chicago Terminal Commission. In connection with the straightening of the river, I wondered if the author has prepared any estimate as to the cost or method of financing the proposition, whether any consideration has been given to the balance of benefits and damages in the straightening problem.

Mr. Noonan: Two or three years ago a rather careful estimate was prepared of the cost of straightening the river and I believe that included the work of actually creating the new channel, lining

it with modern wharves, and filling up the old channel. That estimate, depending upon whether one or two procedures could be followed, varied between seven hundred fifty thousand and a million dollars, just for the bare making of the channel. There have been no efforts made to arrive at any plan for the apportioning of that cost or the apportioning of the benefits, because we have been always working upon the plan of being able to bring that about by coöperation among the railroads. All of the property abutting on the river is owned by railroads, and if they could among themselves work out that problem it would probably wash. If the city should undertake to do it then they would have to appoint some assessment commission or somebody which would assess damages and benefits.

There is another element in that, and that is the old channel. Who does that belong to? Does it belong to the state? Some say it does. If it does, the value of it as real estate might pay for the cost of the improvement. But then you get into the other question of putting viaducts across there where you would open new streets. If the railroads got the use of the property under the streets they might be assessed a portion of the cost of the construction of the viaducts. Some other portion of it might justly be assessed against the city as a whole. But those details have never been worked out because we have never gotten to the point where a concrete plan was under consideration.

E. S. Nethercut, M. W. S. E.: I trust that in considering this problem we will consider it as a problem which must be worked out in a coöperative manner. I do not wish to under estimate at all the interest or the influence of the railroads in this matter, but I am impressed with one thing that possibly has been overlooked to a certain extent in the railroad development. We do not have to go far through this city to find instances where railroads have been developed at the savings of a few dollars, or hundreds of thousands of dollars, possibly, with the result that the citizens are somewhat circumscribed and restricted in their rights. I am sure that the railroad engineers of the present day look upon this in a broader light than some of their predecessors. I am quite sure that public sentiment is more directed towards these problems than they ever were before. I am very sure that the work of such commissions as are represented here bring an intelligent manner of discussion of many of these problems, and when we enter into a discussion of this problem with an attempt to make a solution of it on the broad grounds of the versified interests of our railroads, the tremendous power that the railroads have in the development of a city like Chicago, and also the right of free access to the various parts of the city, we will be able to get the proper solution of a problem of this kind. It is a matter which not only involves engineering but the larger aspects of engineering, which have to do with the conservation of energies as well as dollars, and in the light of this attempt to solve a problem of this kind, I am sure Chicago terminals will be very much better in the future than they have in the past.

Chicago & Northwestern Railway Co. Terminal Grain Elevator *

By W. H. Finley, m. w. s. e.
President, Chicago & Northwestern Railway Company.

Presented March 10, 1919

THE elevator is located on the west bank of the Calumet River, near 122nd Street, in the City of Chicago. The Calumet River has a channel 200 feet in width at the bottom and a project depth of 21 feet. It empties into Lake Michigan about four miles northeast of the elevator site at the South Chicago Harbor.

The location permits grain to be received both by rail and water, as well as being shipped out in like manner. The daily receiving capacity by rail is 1,296,000 bushels, and the daily shipping capacity by rail is the same. The daily receiving capacity by boat is 480,000 bushels, and the daily shipping capacity by boat is 1,440,000 bushels. All of the above operations may be carried on simultaneously. The handling capacity, of course, depends upon the receiving capacity, which is 1,766,000 bushels per day, or, expressed in car units, would amount to over 1,000 cars per day.

RAILWAY FACILITIES

Taking into consideration the relation of the property with reference to the river and the connecting railway, the problem of the location of the elevator and arrangement of tracks to serve it was one that required considerable study. It was finally solved as shown on general plan of yard.

This layout permits the rapid handling of cars to and from the elevator, with minimum amount of switching. The yard contains 18 miles of tracks and is divided into receiving tracks, running tracks, storage tracks and hopper tracks. The hopper tracks are so arranged that cars go through the track shed, depositing or receiving grain, as the case may be, and are taken away by a gravity system of switching. The capacity of these yard tracks is 1,250 cars. Provision has been made for a future double-track line to pass between the storage house and the river house to serve other industries which may be constructed along the river front.

In connection with the yard operation there was constructed a three-stall brick engine house for switch engines, a fifty-ton capacity mechanical fuel station, a 47,000-gallon water tank and car repair shops and tracks.

ELEVATOR AND AUXILIARY BUILDINGS

Foundations.—Several borings were made at the site of the structure, all of which were carried down to solid rock, which

*Paper read by F. C. Huffman, principal asst. engineer, C. & N. W. Ry.

was from 72 feet to 75 feet below the surface of the surrounding ground, which had an elevation of from 2 feet to 4 feet above Chicago city datum, the zero of which is at mean water elevation of Lake Michigan. The average formation showed the following:

From top of ground to two feet below, turf; from two feet to twelve feet, quicksand; from twelve feet to thirty-eight feet, blue clay, very hard at bottom; from thirty-eight feet to seventy-three feet, hard pan; from seventy-three feet to seventy-five feet, shell rock; at seventy-five feet struck solid rock.

Test piles were driven and after very hard driving it was able to get a penetration of thirty-six feet to the underlying hard pan and the pile began going to pieces under the hammer at this depth. The pile was then cut off and loaded with a sixty-five ton load. A very slight movement of the gauge showed about one-sixteenth-inch change, which was due to the compression of the fibre in the timber under the heavy load. It was decided from the investigation that piling ranging from thirty-eight feet to forty feet would be the desired length. The design of the foundation required the loading of each pile to be twenty tons per pile. This required the piles to be placed two and one-half feet, center to center, in either direction.

The contract for pile foundation was let to the Great Lakes Dredge & Dock Company of Chicago, Illinois, in September, 1915, and the completion of driving, 18,200 piling, was accomplished in May, 1916. After the piles were cut off a concrete mattress was poured over the entire area. This mattress consisted of gravel concrete, heavily reinforced with steel bars, and varied in thickness from 1′6″ to 2′4″.

Main Structure.—The main structure consists of track shed, drier building, work house, storage house and river house, forming one unit.

The receiving track shed is on the west side of the work house and is 285 feet long, 96 feet 6 inches wide, built of structural steel, and spans five tracks. In this shed are 24 receiving hoppers, which permit the unloading of 24 cars of grain simultaneously.

The drier building, of structural steel, is located over the track shed adjacent to the work house. It is 28 feet wide, 180 feet long and 99 feet high and contains 12 drier units, each with a capacity of 750 bushels per hour, in which grain will be dried before elevating into the storage bins. The units are made up of the following types: six Ellis, three Hess and three Morris.

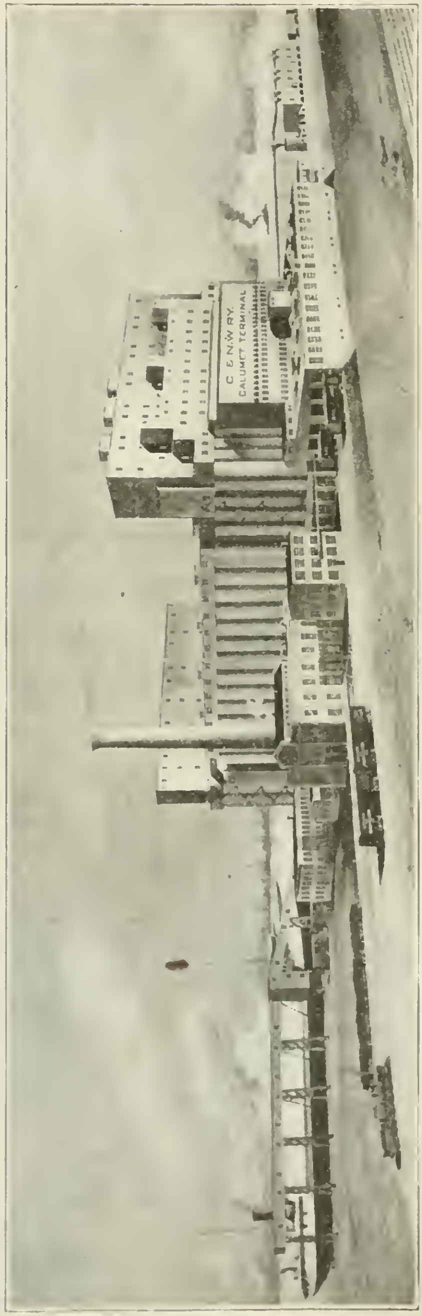
The work house consists of a first story, 25 feet high, for cleaning machinery, over which are 95 reinforced concrete storage bins, 15 feet in diameter, with 7-inch walls. These are surmounted by a cupola of about 93 feet high of structural steel, with reinforced concrete curtain walls. The top of the cupola is about 215 feet above datum.

The first story, which supports the bins, is of structural steel encased in concrete. It is equipped with six receiving legs, six shippings legs, eight cleaner legs, five dipper legs, three screening

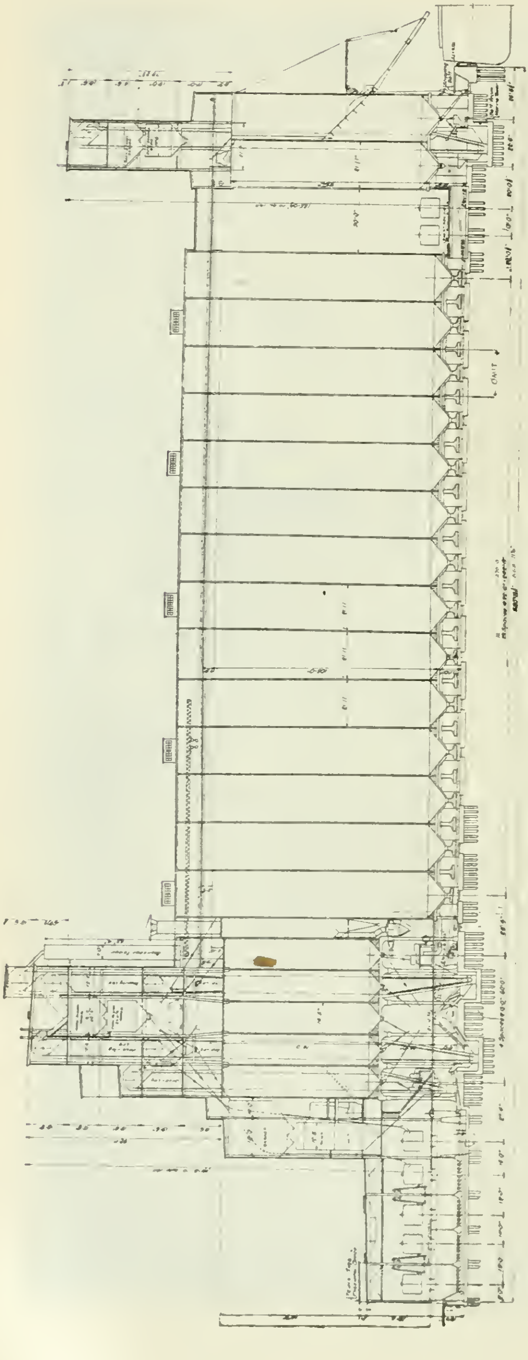
legs, six drier legs and three bleacher legs. The bins above the first story have a storage capacity of 931,000 bushels.

East of the work house and between it and the river house are located the main storage bins, 104 in number. These bins are of reinforced concrete, 21 feet 11 inches inside diameter, with walls 7 inches thick, reinforced with vertical bars and flat hoops, and are 104 feet high. On top of the bins is the belt gallery of structural steel, with walls of cement plaster on wire mesh. The total height of the storage house is 139 feet.

The river house, just east of the storage house, has six shipping legs and fronts on a concrete wharf 1,200 feet long, along the west bank of the Calumet River. It consists of a first story of reinforced concrete, 18 feet 9 inches high, above which are 24 circular bins of reinforced concrete, 21 feet 11 inches in diameter and 95 feet high, with a storage capacity of 778,000 bushels. Above the bins is a cupola 45 feet by 270 feet and 77 feet high, of structural steel, with reinforced concrete floors and cement plaster walls. In this cupola are located the scales and garners. The total height of this structure is 194 feet. At the south end of this river house is located the marine tower, 153 feet high, of structural steel and cement plaster walls. It has a marine leg 96 feet long for unloading grain from boats and delivering the same to the river house for further



C. & N. W. Ry. Terminal Grain Elevator at South Chicago



General Cross Section, C. & N. W. Ry. Company's Elevator, South Chicago

disposition. The wharf is of reinforced concrete supported on piles. It is 1,200 feet long and 9 feet above the water. It will permit the unloading of one boat and the loading of another simultaneously, or the loading of two boats at the same time. The shipping gallery is located on the north side of the river house along the dock. It is used for trimming loaded boats while other boats are receiving their main load from the several spouts on the front.

North of and adjacent to the grain elevator are located the following auxiliary buildings:

Welfare Building — A two-story brick structure 82 feet by 65 feet, furnished with all modern equipment for taking care of the employes.

Office Building— A three-story brick structure 42 feet by 58 feet. In addition to the office space, it also furnishes sleeping rooms and dining room for the officers and operators of the grain elevator.

Shop Building—A one-story brick building 82 feet by 32 feet, used for housing equipment and for making repairs to machinery.

South of the elevator is located a one-story brick dust house built on an elevated reinforced foundation. It receives the dust and cleanings from the grain for the purpose of sacking and disposition as a by-product.

The sulphur storage house, a one-story brick building 30 feet by 17 feet, is also located south of the elevator.

The following statement of the quantities of material used in the construction, and the capacity of the different units, will give one an idea of the size of this structure:

Excavation, 80,000 cu. yds.
Foundation piling, 18,200 pieces, 698,000 lineal feet.
Concrete, 62,000 cu. yds.
Reinforcing steel, 1,750 tons.
Structural steel, 5,400 tons.
Elevating and conveying belting, 52,033 lineal feet (10 miles).
Form lumber, 1,900,000 feet BM.
Cement, 94,000 barrels.

Operating facilities:

	Bushels
Storage capacity, with 182 storage bins	10,000,000
Storage capacity, with 104 storage bins	6,000,000
Daily receiving capacity by cars	1,296,000
Daily shipping capacity by cars	1,296,000
Daily receiving capacity by boat	480,000
Daily shipping capacity by boat	1,440,000

The storage bins are equipped with a Zeleny thermometer system, which registers the temperature in all the bins at 5-foot intervals. If the grain in the storage bins shows any undue heating, the entire capacity of these bins can be turned over in two days.

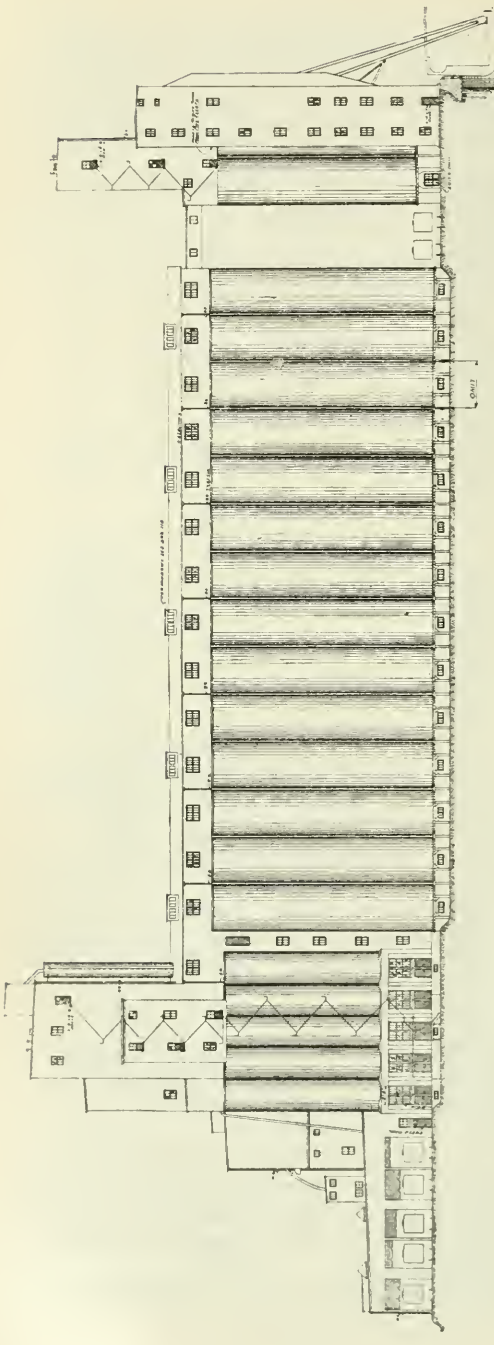
The elevator and auxiliary buildings above described were designed by the John S. Metcalf Co., Ltd., grain elevator engineers, Chicago, and the general contractors were the Witherspoon-Englar Co., Grant Smith & Co., of Chicago. The elevator conveying and transmission machinery was furnished by the Webster Mfg. Company.

POWER HOUSE

The power house was designed to furnish electricity to operate the grain elevator and steam for grain drying, for heating and for operating refrigeratory machinery installed as part of the equipment of the grain elevator.

The building housing the steam and electric generating and control equipment is erected on a pile foundation and is of steel, concrete and brick construction, with overall dimensions of about 125 feet by 82 feet, and a height of 73 feet through coal bunkers and 50 feet the balance of the building.

The location of the switch structure is on a mezzanine floor above the turbine room.



South Elevation, C. & N. W. Ry. Company's Terminal Grain Elevator at South Chicago

Boiler Room.—There are at present installed three batteries of two boilers each. The boilers are arranged with two batteries on one side of a central firing aisle, one battery on the other side, with space for an additional battery.

The boilers furnish the necessary steam for operating the turbine-driven generators and steam-driven auxiliaries in the plant, steam for heating purposes, for operating a refrigerating plant, and in addition approximately 40,000 pounds of steam per hour for grain-drying purposes.

The design of the boiler plant is such that the maximum requirements of the grain elevator as at present installed can be taken care of with five boilers, thus allowing one boiler to be shut down for cleaning and repairs.

Each of the boilers is of the Babcock & Wilcox make, Stirling type and in addition to being provided with a 6-retort Westinghouse underfeed stokers and Vulcan Soot blowers are provided with Babcock & Wilcox superheaters. The boilers have 5,020 sq. ft. of heating surface each

and will be operated at 200 pounds gauge pressure; the temperature of the steam will, however, by means of the superheaters, be increased 150 deg. F. above that corresponding to this pressure.

The stokers are driven by means of four Westinghouse Standard engines, arranged two on either side of the central firing aisle. Forced draft for operating the underfeed stokers is supplied by Buffalo fans, connected by means of gearing to Westinghouse high-speed turbines. There is also provided a 12 foot by 203 foot Custodis radial brick stack that will take care of the ultimate capacity of this plant.

Coal is delivered to the power house from cars, discharging into a track hopper fitted with a coal crusher and feeder, which empties into the boot of a vertical bucket elevator. The elevator discharges into a belt conveyor on which the coal is distributed by means of an automatic tripper to the coal bunker serving the boilers, which is located overhead in the central firing aisle between the boilers. Chutes fitted with measuring hoppers convey the coal from the overhead coal bunkers to the stoker hoppers. The overhead coal bunker holds approximately 500 tons. The stokers discharge the ashes into ash bins directly underneath, from which point they are handled by means of a steam jet conveying system to an overhead ash bunker arranged to empty into cars.

Water for boiler feed purposes can be taken from either the Calumet River or the city mains. It is discharged by means of service pumps to an open-feed water heater and from the heater to the boilers by means of turbine-driven boiler feed pumps.

The boiler room also contains a 1,000-gallon Underwriters fire pump with steam end especially designed for use with superheated steam.

TURBINE ROOM EQUIPMENT

The turbine room equipment consists of the following generating and sundry apparatus, furnished by the Westinghouse Elec. & Mfg. Co.:

Two 1,500-kw. 2,300-kva 65 per cent P. F. 600-volt, 3-phase, 60-cycle, 3,600-r.p.m. turbo generators.

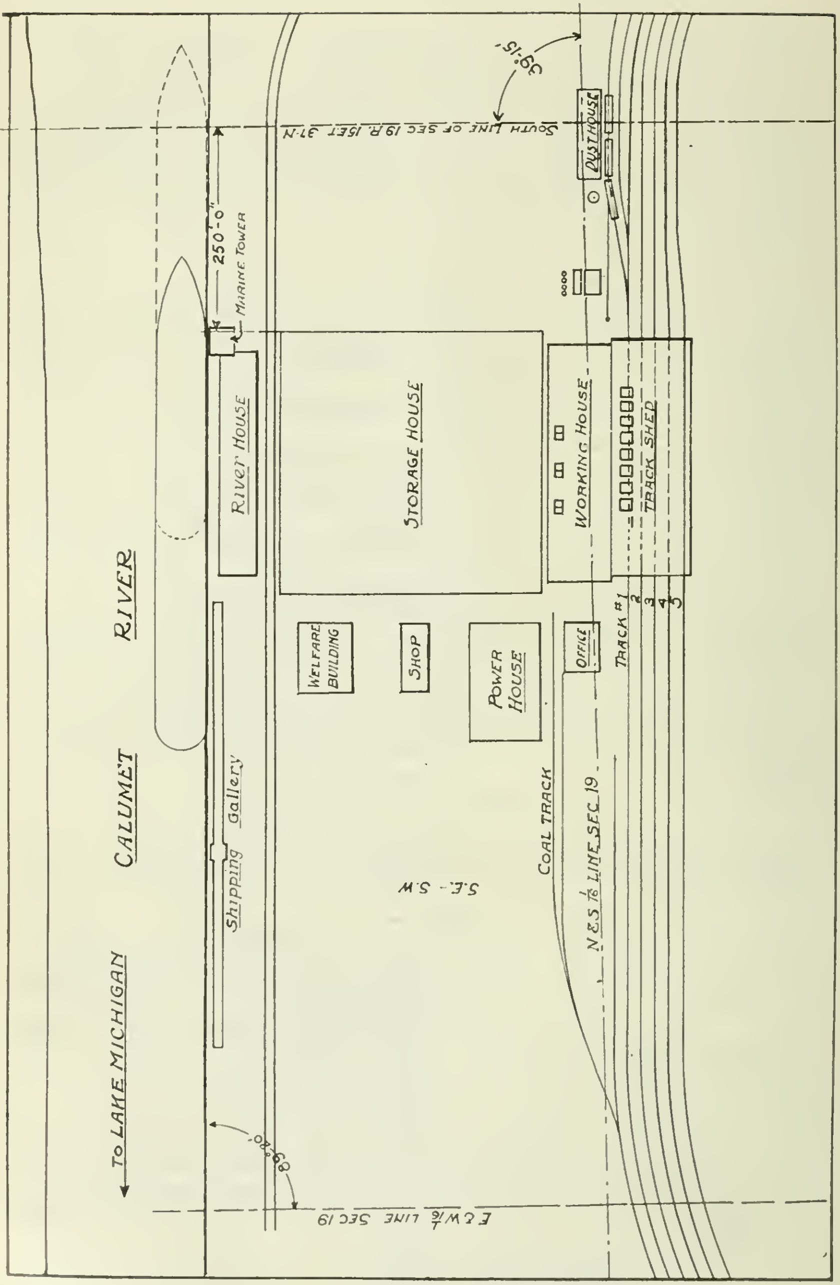
One 500-kw. 770-kva. 65 per cent P. F., 600-volt, 3-phase, 60-cycle, 3,600-r.p.m. turbo generator.

One 50-kw. 125-volt exciter, driven 1,200-r.p.m. by 7,200, r.p.m. geared turbine.

One 50-kw. 125-volt exciter, driven by 1,200-r.p.m. induction motor.

One 12½-kw. 160-volt, 1,800-r.p.m. motor generator, set for charging a battery consisting of 55 Electric Storage Battery Co.'s cells, type E11, which is used for supplying current for operating the oil switches and signal systems in the grain elevator.

Two small motor generator sets for automatic telephones and telautograph systems.



Plan Showing Arrangements of Tracks and C. & N. W. Ry. Elevator at South Chicago

Space is provided in the turbine room for an additional 1,500-kw. unit. Water for condensing purposes and for a relay for boiler feed is obtained from the Calumet River, there being two 36-inch C. I. pipes, one serving as an intake pipe and one for an overflow pipe. These pipes connect the Calumet River with the intake and overflow flumes located under the floor in the turbine basement.

Each turbine has an individual Westinghouse LeBlanc condenser, turbine driven.

The switching consists of a switchboard, located in the gallery, for the control of the main generator and feeder oil switches, which are in the basement; also an auxiliary switchboard, likewise located in the gallery, for the control of the exciters, storage battery and lighting circuits.

The bench board is a 10-panel board controlling the two 1,500-kw. and the one 500-kw. generators, with a blank panel for future generators, and contains the totalizing panel and five feeder panels, each controlling four feeder circuits.

The oil switches are mounted in a standard concrete double-cell structure and the operating solenoids for the main generator switches are in the passageway between the compartments. The solenoids for the feeder switches are mounted underneath on the oil switch frame. The chief point of interest in reference to the switching equipment is Westinghouse multiple multipole oil switches using four 800-ampere single-pole elements for each phase of the 1,500-kw. generator.

A unique feature of the feeder equipment was the installation of a special push-button switch controlling each feeder and located in the grain elevator at the point where the feeder enters the building. These control switches are so connected that, being closed, they trip the circuit breaker in power house and this breaker cannot be reset until the control switch at the elevator is again placed in the open position.

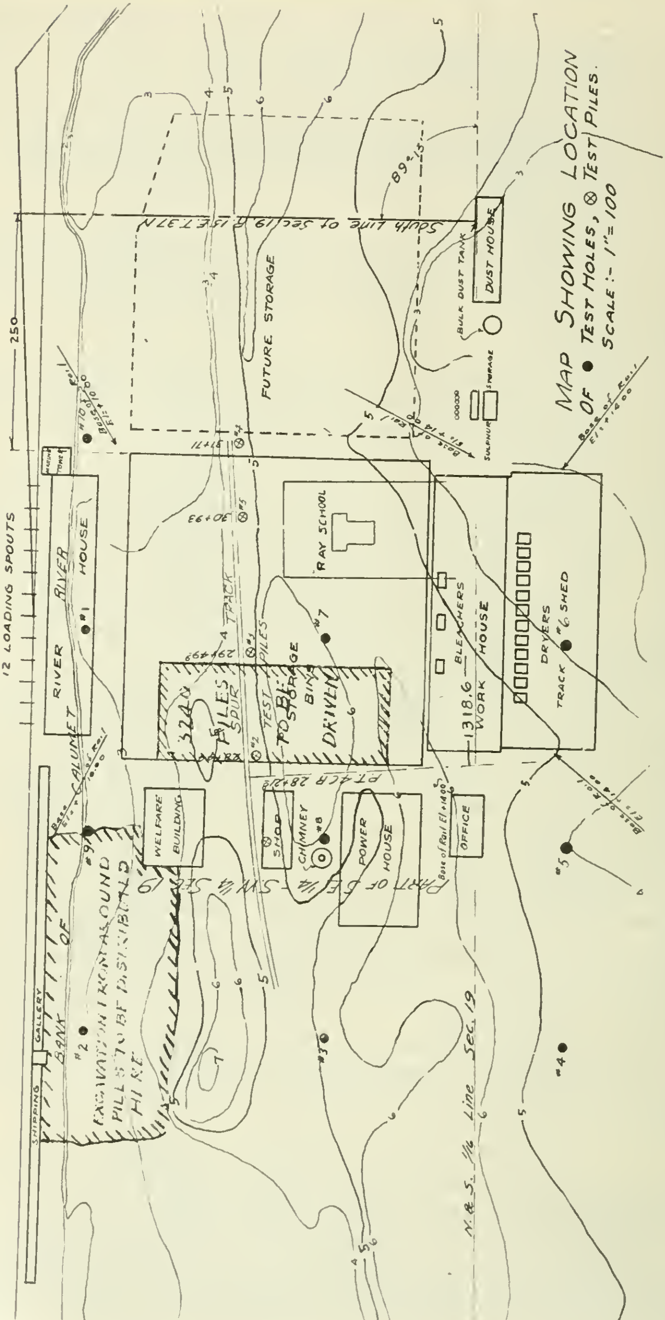
The lighting of the station is by means of high candle power tungsten lamps, with deep bowl, enameled steel reflectors, and the circuits are so arranged that lights can be run from either AC lighting transformers or from the batteries. In addition, there is provided an emergency circuit throughout the station, operating from the storage battery.

The power plant above described was designed and constructed by the Westinghouse Church Kerr & Company, engineers and constructors, 37 Wall Street, New York.

CONTRACTORS' CONSTRUCTION PLANT

Contractors for the elevator proper installed a very complete and well laid out plant to carry on this work.

The plant consisted of an elevated railroad track for receiving sand and gravel in hopper bottom cars, which were dumped from trestle into hopper, from which a belt conveyor carried the material up an incline of 20 degrees to the horizontal, to a height of 40 feet,



Map Showing Location of Test Holes and Test Piles

where it was dumped and uniformly distributed by a traveling tripper into a large storage bin 200 feet long. This bin was divided into a compartment for sand holding 1,000 cubic yards, and the remaining portion for holding gravel to the amount of 2,000 cubic yards. This bin had a sloping bottom and had a belt conveyor running the entire length underneath, which received the material from the large bin and carried it to a cross belt, which again elevated the material to a height of 40 feet, where it delivered it to a long belt running parallel to the building. This belt delivered to three separate mixing plants, equally spaced, near the side of the structure. Each mixing plant had a sand hopper of 40 yards capacity and a gravel hopper of 80 yards capacity located directly

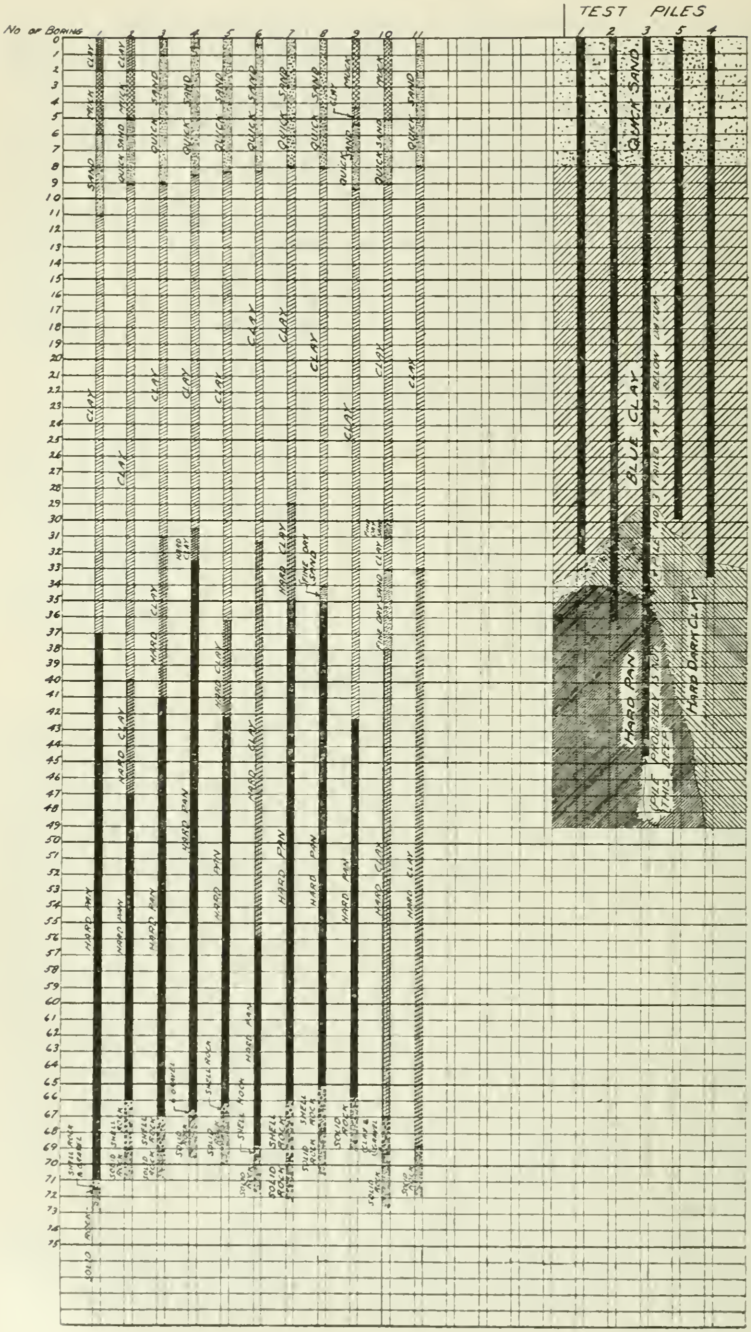
No. of Pile	Kind of Material	Length in Feet	Diameter of Pile in Inches			Total No. of Blows Struck	Penetration in Feet	Penetration Last 10 Blows Inches	Average Drop of Hammer Ft.	Penetration Last Blow Inches	Drop in Ft. of Hammer Last Blow	Bearing Power in Tons	Remarks
			Butt	Middle	End								
1	Southern Pine	36^{2}	13	11	9	330	37	7	18	3/4	18^{3}	29^{3}	[illegible] Drove Very Hard. Excavated 4 Ft. For [illegible]
2	Hard Maple	43^{0}	13	$11\frac{1}{2}$	$9\frac{1}{2}$	713	41	$4\frac{1}{4}$	10	5/8	15	25^{8}	Main Pile 37 Ft Long Follower Pile 6 Ft Long Very Hard [illegible]
3	Southern Pine	51^{0}	13	11	9	793	49^{7}	12	10	$1\frac{1}{8}$	15	21^{1}	[illegible] 35 Ft Long Follower Pile 15 Ft Long Pile Found At 35 Ft In Ground Very Hard Driving Bearing Power At 35 Ft Penetration [illegible]
4	Hard Maple	43^{0}	$13\frac{1}{4}$	12	9	613	37^{6}	6	15	3/4	15	24^{0}	This Pile Drove Very Hard Excavated 7 Ft In Order To Get Pile In Leads
5	Southern Pine	35^{8}	14	$11\frac{1}{2}$	$9\frac{3}{4}$	310	34^{4}	$10\frac{7}{8}$	18	7/8	15^{5}	23^{1}	Pile Drove Very Hard Loaded With 31 Tons No Settlement Two Days After Loaded To 56 Tons, 0.03 Ft Settlement Loaded To 60 Tons No Additional [illegible]

Record of Driving Test Piles, Drop Hammer, Track Driver. Weight of Hammer, 2,800 pounds.

over the mixer. The material was delivered to the mixer through measuring chutes. The cement in most cases was taken directly from cars, which were brought opposite each mixer on a material track. A 600-barrel cement shed was built at each mixer plant to store cement in case cars were not regularly delivered. Water was supplied from the river by the use of a motor-driven triplex pump, automatically controlled by cut-off switch, at a maximum pressure of 80 pounds. A one-yard electrically-driven mixer was installed at each plant. After the concrete was mixed it was dumped into hoisting buckets at each of the three plants and hoisted to proper height, where it was delivered to distributing chutes. The distributing chutes had a swivel leg and balanced cantilever discharge spout operating in a radius of 100 feet. This method of handling the concrete was used for all the foundation slabs, basement walls and bin floor slabs. Above these it was sliding form work and the "buggying" method was used. Each of the concrete plants was able to deliver 1,200 yards during a period of two ten-hour shifts. When operating at capacity a batch of concrete was turned out every 47 seconds.

All conveyors, hoists, mixers and machinery were electrically driven by current brought in at 12,000 volts and stepped down to 220 volts at a temporary transformer building on the site.

This work was carried out under the direction of the writer



Nature of Excavation Below Lake Datum

as chief engineer of the railway company. Mr. F. C. Huffman was resident engineer; Mr. W. T. Main, assistant engineer, and Mr. B. M. Lockard, assistant engineer.

DISCUSSION

W. S. Lacher, M. W. S. E.: We all have rather vague notions that an elevator is a place to put grain in; it is shipped in and it is shipped out, and perhaps cleaned, but my notions, at least, are very vague. This plant provides for receiving grain and also for reloading cars and boats and hauling away. Just what is the object of an elevator of this type? Is it for the purpose of accumulating a large amount and holding it in storage? Also for what is the sulphur used?

Mr. Huffman: Grain elevators, as applied to the storage of grain, are as old as civilization. In the earliest days we find the people in the Egyptian countries building them where carvings show grain elevators for storing grain in bins not unlike what we are building today. The work done now by up-to-date machinery was then performed by man power, carrying the grain up flights of stairs to the top of the elevator—which we would not care to do today. From this type of grain storage we get the term used in elevators today, the "elevator leg." I presume this has been handed down to us since those early days. In those times they built elevators of a certain size and they carried the grain in by hand and stored it. That was all well and good when each year produced grain and one could go out into the field and cut it, bring it in and store it, take it to the mill and have it made into the daily bread. But along comes somebody with power above ours who says, "You raise no grain this year." So the building of large elevators was found necessary, and we find big elevators and big operators going hand in hand for taking care of the grain for the lean years.

Another function is that of receiving grain, storing it and thrusting it on the market when a profit can be made for the operator. Another is receiving grain which has been damaged by the elements before being harvested. This grain, without such an apparatus for handling and treating as we have in this elevator, would be fed to the hogs. After it has passed through this elevator it is fed to hogs and more hogs, but it is in much better shape then for the four legged fellows.

The sulphur is used for bleaching purposes. I have seen some grain come in to the elvator which I said was spoiled, but to the operator of the grain elevator it was not spoiled, for after the oats had been treated and dried I know I could not—I do not know whether anybody else could—tell it from the best oats ever put on the market. There are sulphur furnaces and this sulphur is pumped through the sulphur bins, and I believe the grain is dropped through these fumes, which carries on a bleaching process, for which sulphur is noted. After this treatment the grain is graded and put

on the market in a bleached condition, the smut and the rust having been removed.

Mr. McDonald: Sulphur is used only in the treatment of oats. No other kind of grain is brought into contact with the sulphur fumes. In certain seasons, such as some of us have seen, the oat crop is harvested wet and it becomes discolored. Of course it has to be marketed and this grain comes to the elevator with a brown color. That stain can be entirely removed by the sulphur treatment. The elevator is provided with an apparatus by means of which the grain is brought into contact with the sulphurous acid. The bleacher is usually a concrete tower provided with ducts and connections to a furnace where the sulphur is burned. The grain is first moistened with water. The sulphur treatment is then applied, and the fumes coming from the burning sulphur, uniting with the water, forms sulphurous acid, and this acid immediately gives a bleaching effect to the grain. From the bleacher the grain is usually drawn into dryers where the excess moisture is removed. It is for that purpose, and for that purpose only, that the sulphur is used in the treatment of grain in this elevator.

J. C. Blaycock, M. W. S. E.: The question was asked, "What is a grain elevator for?" In shipping new grain, unless it is turned it will soon "foam," i. e., if new grain is put into cars and allowed to stand, the heat will cause it to decompose very rapidly, and it will foam. For that reason it is brought to the grain elevators and dumped into the receiving hoppers and transferred into the bins. In two or three days it is turned, until it has a chance to be dried. In this way the grain is saved.

Mr. Lacher: The speaker made one statement in regard to loading the boat and moving it down to the loading gallery for trimming. This seems like a loss of operation. Why start a boat in and load it at the river house and then move it down the loading gallery three or four times to top off the load?

Mr. Huffman: The reason of that is, when you load the boat it is the same as when you load a box; the grain will take a decided slant or slope when the hold is full and form a certain angle. You want to load the boat to capacity and you want to get the holds filled up level full or as near so as you can. You have a smaller spout and slower operation and here the men can work slowly and give the loading apparatus in front of the elevator proper the advantage of quick loading of the boat up to this point. They shovel the grain around and level it off up with these slow moving spouts. It has that additional advantage; that it would be a loss of from ten or twelve percent if that boat would be loaded without the trimming.

Question: Was not it the intention that this trimming operation was in case another boat was waiting at the river house to be loaded so as to save time?

Mr. Huffman: I wouldn't want to make that statement myself, because the economical loading would be the rapid unloading mech-

anism in front of the shipping house, which is a great deal more rapid than the shipping gallery. It would probably be wise to let the other boat wait if that was the point. I think the shipping gallery was wholly for the trimming of the boat alone.

Member: In loading a boat the oats are taken up to the house proper and loaded. All the grain possible is dropped into it in a short space of time. Then the boat is moved up to the trimming gallery to give the trimmers a chance to trim the boat. While it is there the second boat gets up and secures the bulk of its load, and the performance is repeated.

Question: Why did the Northwestern Railroad build such a tremendous structure entirely out of the zone of its own tracks? How is this sulphur used in the bleaching operation, and what means are there of getting rid of the vermin in the grain, such as weevil and other things. It would be interesting to know how much this elevator cost per bushel of storage. It would also be interesting to know how much this elevator cost per cubic yard of concrete employed in its structure. As a general thing, when a man is making a hop-skip and a jump of an estimate he wants to know what it costs. It would also be interesting to know what that iron work cost.

Mr. Huffman: The first question is about the Chicago and Northwestern Railroad, as to why they built their elevator at this point. I expect you would have to go to the board of directors to get that information. For a number of years they have been buying up that land down there. Of course, the Northwestern Railroad taps a very large grain producing country, and an operating feature of the raliroad is to bring that grain to the city of Chicago and then turns it over to the three or four branch lines to get it to the elevators that were in operation up to the time this structure was contemplated. It meant the absorbing of all those switching lines here in the city of Chicago. In that I think you will find one of the reasons for the building of this elevator where it is. There was no other place of such inviting features for a grain elevator in the city as this particular point, having deep waterway and a tract of land where tracks were available. In other elevators in the city the cars are shoved in to the elevator, probably two or three beyond, and then loaded and taken out of place for the others to be loaded. The operation is practically cut in two by such arrangement as we find here. I don't know how they get the weevil out of it unless they go through the blower system. Mr. Stewart can tell you how they get the weevil out of the grain.

Mr. Stewart: We never have any weevil down there.

Mr. Huffman: The cost per bushel would be covered in Mr. Finely's paper. Its storage capacity in the present condition is about six million bushels. The design is for ten million bushels, which would only need the addition of six rows of bins to bring the capacity up to that. The cost now per bushel would be around seventy-five or eighty cents. If you had the other five bins you

could bring the cost down to less than fifty cents per bushel. The cost per yard of concrete could be obtained by taking the sixty-two thousand cubic yards of concrete and dividing it by the cost. I think the estimate on the concrete for any additional work we asked was done, not in accordance with the contract, but in the neighborhood of ten or twelve dollars, depending upon the mixture. The concrete on these walls, being only seven inches thick would not run into yardage very rapidly. The slabs and the mattresses, when they were poured, as I remember the progress reports, the concreting was over fifty percent done before anything had started to go into the air.

Mr. Munn: How many carloads of machinery did Mr. Perkins here furnish? I think it was in the neighborhood of about seventy-five car loads, but I am not certain.

Mr. Perkins: There were about seventy-five or eighty cars. I think the machinery averaged about sixty-five hundred or six thousand dollars a car. There were so many spouts in that elevator down there I thought we never would get through making them. There are also about ten miles of belting in the structure. They have facilities for unloading twenty-four cars at a time with portable shovels, and I think they average about two cars an hour according to Mr. Huffman's statement. They ought to average about three cars an hour or better.

Mr. Reichman: The rapid development of the elevator business has been a direct result of the fact that we have been able to develop a reinforced concrete elevator. Concrete makes a very desirable bin for an elevator; it is cheap, efficient and fireproof and has all the good qualities that are required for storing grain. There is nothing special about any of these details, and nothing difficult about it from a scientific standpoint. It is more difficult from the standpoint of detailing and fabricating than otherwise.

Municipal and Hydraulic Engineering in Washington's Day

By Charles B. Burdick, M. W. S. E.

AS a background for a view of the municipality in the latter half of the eighteenth century, it should be noted that although the dark ages were several centuries past, the progress toward better living had been extremely slow. In the preceding century there had been forty-five epidemics of the black death in Europe. In 1665 there were 65,000 deaths in London alone, out of a population of 200,000. Asiatic cholera occasionally visited Europe even a century after Washington's day.

Better sanitary conditions in the cities are well illustrated by the increasing span of life, the best available statistics indicating an average life of twenty-three years in the eighteenth century, thirty-two years in 1825, thirty-seven years in 1867, and over forty years at the present time.

Washington's life spanned a period from 1732 to 1799. Virginia was his birthplace and his home during nearly all his life. He was a citizen of a nation which in 1783 numbered only about two and one-quarter million white people. His native state, with three-quarters of a million people, led the union of states in population, with Pennsylvania, North Carolina, Massachusetts and New York ranking in the order named. The population of New York State was 340,000. In 1790, the chief city, New York, had a population of 33,000. The population of Philadelphia was 28,000; Boston contained 18,000 people. The population of Baltimore was 13,000.

McMaster, in his history of the people of the United States, furnishes a good picture of municipal conditions in 1784. Speaking of Boston, he says:

"The streets of the city were laid out with no regularity, and were given names, which, either from their English associations, or the coarseness of the times they recalled, were, by a more refined generation, gradually changed. George Street has thus become Hancock Street; King has been changed to State; Queen to Court; Marlborough to Washington; what was once Black Horse Lane is now Prince Street; Cow Lane is now High Street; Frog Lane is now Orange Street, Hog Alley is Avery Street, etc."

"The carriage-way along these narrow lanes and alleys was unpaved; the sidewalks or footways were unflagged. Each was, in the language of the time, pitched with large pebbles, and the footway was marked off from the carriage-way by a line of posts and a gutter, after the manner of many old English towns. The roads were such as would now excite the indignation of a country newspaper. The pebbles were ill-laid and ill-kept. Yet travelers admitted the road was as good as could then be found in many

parts of London, and the horseman who galloped over it was fined to the amount of three shillings and fourpence."

"As to the houses which lined the streets on either side, they were, in the older portion of the city, mean and squalid. Built entirely of wood, with unpainted weatherboard sides and shingle roofs, surmounted by ugly wooden railings, within which, every wash-day, shirts and petticoats flapped in the wind, they contrasted strongly with the better class of dwellings on the west side of town. There the streets were neater, the houses of brick with Corinthian pilasters up the front, and columns of the same order supporting the porch, and handsome entrances to which led up a long flight of sandstone steps, stood back in little gardens, dense with English elms and shrubs."

He speaks of New York as follows:

"In the city hardly a street was paved, and these few were so badly done that Franklin observed that a New Yorker could be told by his walk as he shuffled over the smooth pavements of Philadelphia. Street lamps, which came into fashion ten years before, were few in number, and rarely lighted on wet nights. Tin gutters projected from the roofs far out over the foot-paths, and in rainy weather, discharged torrents of water into the unpaved streets, drenching the horseman and splashing the foot-traveler with mud from head to foot.

"To the south of New York, no place of importance was to be met until Philadelphia was reached. The city was then the greatest in the country. No other could boast of so many streets, so many houses, so many people, so much renown. There had been made the discoveries which carried the name of Franklin to the remotest spots of the civilized world. There had been put forth the Declaration of Independence. There had long been held the deliberations of Congress. No other city was so rich, so extravagant, so fashionable. Seven years before, Lee had described the place as an attractive scene of amusement and debauch. Lovel had called it a place of crucifying expenses, and this reputation is still maintained. But the features that most impressed travelers from distant lands were the fineness of the houses, the goodness of the pavement, the filthiness of the carriage-ways, the regular arrangement of the streets, and the singular custom of numbering some and giving to others the names of forest trees."

Sewers there were none. In fact, the city of Chicago built the first general municipal sewer system on this continent. Outhouses were maintained in the rear of the dwellings, and the kitchen slops were, to a large extent, thrown into the streets and alleys, and the storm water ran away through the streets and gutters. Even in London, sewage proper was excluded from the drains by law prior to 1815, and it was not made compulsory to use the sewers for this purpose until 1847.

Our first municipal water works was built in Boston, in 1652. It was a gravity supply from springs. A municipal plant was built

in Bethlehem, Pa., in 1754, in Providence, R. I., in 1772, in Morristown, N. J., in 1791. In 1800 there were sixteen municipal water works, since which time the growth in municipal water supply has fairly kept pace with that of the cities.

The first use of steam for pumping occurred in London in 1761. The first American installation was at Philadelphia in 1800. Steam was applied to New York's water supply in 1804.

Although a part of New York had been supplied with water as early as 1774, the first comprehensive system was built the year that Washington died, 1799. An old tank which supplied a pipe system of pine logs was torn down recently. It was 40 feet in diameter, 20 feet high and constructed of ribbed cast iron plates 2½ by 4½ feet and ⅝ inch thick.

The early water works furnished a supply only at certain hours of the day. A constant supply was only introduced in London in 1873, and as late as 1891, 35 per cent of the supply was still on the intermittent system.

Probably our first example of town planning upon a comprehensive scale was the District of Columbia and the city of Washington, which was laid out upon virgin soil. The plans were drawn, and the early work of construction was carried out by Major L'Enfant. In this work George Washington took a lively interest, and devoted much time to the study of the plan and its execution. Again quoting from McMaster:

"Farmers, whose lands the city would cover, were persuaded to deed them to the Federal commissioners to be laid out into streets and squares, parcels and lots. No compensation was given. Major L'Enfant took what land he wanted for public buildings, streets and parks, marked out the remainder into lots, gave back half of these to the grantors, and kept half for the United States. Much that appears upon his map does not exist elsewhere. . . . East Capitol Street was to be a broad avenue lined with arcades and handsome stores, for east of the capitol was to be the city. Between the capitol and the White House were to be the gardens and the public buildings, and spacious dwellings for the ministers of foreign states. But, long before this scheme could be perfected, L'Enfant had quarreled with the land jobbers, had torn down a house the Carroll family were building across one of his projected streets, had refused to make his plans public, and had been removed from office by Washington."

The spirit of the time was speculative, and there was a ready market for real estate in Washington. It was a difficult matter, however, to induce the people to make the necessary investments in buildings of the proper character.

"The commissioners, therefore, had to resort to that method by which it was the custom to raise money for all manner of public improvements, and, with the help of Samuel Blodgett of Philadelphia a number of lotteries were planned. Early in February, 1793, the public were informed that the purpose of Federal Lot-

tery No. 1, was to build at Washington what was then commonly called a tavern, but what the commissioners, adopting the new French fashion just coming in, called a hotel. The lottery was to consist of 50,000 tickets. The first prize was the hotel, a fine structure to cost precisely $50,000. All other payments were in cash, ranging from $25,000 to $10. The price of a ticket was $7. . . . At a later time, two men of means came forward, bought 6,000 lots at $80, guaranteed to build 140 houses before the year 1800, and to sell no lots to buyers who would not agree to erect at least one dwelling for every three lots sold them.

"A traveler who saw Washington City in 1796 declares that had it not been for the President's house and the capitol he would never have known it to be a city. The gardens, the bridges, the canals, the parks marked down upon the plan were still on paper. Such streets as had been laid out were cut through the forest and reminded him of broad avenues in a thickly wooded park."

Although water has been used for the generation of power from a time antedating written history, large installations only followed the invention of the modern water turbine about 1843. In Washington's time, the installations were confined to overshot wheels and breast wheels constructed of wood, and used for the driving of grist mills and saw mills, usually requiring less than 100 horsepower. Until the turbine was perfected, it was impracticable to develop water in large quantities, and the use of the higher heads has only become practicable since the development of electricity.

In Washington's time the development of the country depended upon transportation. Cheap freight for bulky and heavy goods and produce could be secured in no other way except by navigation. The earliest examples of hydraulic engineering, therefore, consisted of projects for the improvement of the existing rivers and the construction of canals.

Speaking of the conditions in 1792, McMaster refers to the numerous canal projects as follows:

"The time was fruitful of all manner of projects for internal improvement, but the favorite was canal, or as it was called, Canal and Lock Navigation. The rage spread over the whole country, and in a few months plans were afloat for three or four artificial waterways in every state. A society for promoting the improvement of roads and inland navigation in the state of Pennsylvania was started in Philadelphia, and soon three canals were the talk of the coffee-houses."

It was proposed to build these early canals through stock companies, and until there had been numerous financial failures the stock of these concerns was usually over-subscribed. It was necessary in some cases to draw by lot the right to purchase canal shares.

George Washington early became interested in the undeveloped lands of western Pennsylvania and West Virginia. He early saw the necessity for better means of access before these lands could be developed. After he retired from the presidency, he

took an active interest in the attempt to promote water communication between the Potomac and Ohio rivers, and for a time was president of a company which was formed for this purpose. A short stretch of canal in the vicinity of Alexandria, Va., containing a lock was planned and constructed by Washington. The early projects for canalization progressed little beyond the survey stage, and it was not until some years after Washington's death that any important work was completed and utilized.

Proceedings of the Society

Meeting No. 1041, May 5, 1919.

This was a general meeting of the society and was attended by 55 members and guests. Col. L. D. Wildman, department signal officer, U. S. A., Chicago, Ill., gave an address on the scope and development of the Signal Corps. This outlined the scientific advancement made in signal apparatus during the war, which contributed very largely to the success of our armies. The secretary presented an outline of the development of the Western Society of Engineers.

Meeting No. 1042, May 12, 1919.

This was a meeting of the Bridge and Structural Engineering Section, with an attendance of 60 members and guests. G. A. Haggander acted as chairman. E. M. Haas, railroad specialist of the Austin Co., Cleveland, Ohio, presented an illustrated paper on "Modern Tendencies in Engine House Design." This paper showed the progress in designing and the economies, which are now general in railroad operation.

May 19, 1919.

This was a joint luncheon meeting of the Western Society of Engineers and the City Club of Chicago, R. F. Schuchardt, chairman, Public Affairs committee, presiding. The subject of the meeting was "Inland Water Transportation. Is Our Policy Right or Wrong?" Thomas Brendt, traffic manager, Mississippi-Warrior Waterways Barge commission, U. S. Railroad Administration, discussed the present situation, ncluding the costs of operation of various inland transportation problems and their relation to railroad transportation. Prof. Harold J. Moulton, department of political ecenomy of the University of Chicago, presented a wide review of the economies of waterways transportation. This involves a proper inclusion of capital charges for the development of waterways.

Meeting No. 1043, May 19, 1919.

This was a meeting of the Hydraulic, Sanitary and Municipal Engineering section. Attendance 55 members and guests. Linn White, chairman. George W. Tillson, consulting engineer, presented an account of his observations as a member of the commission of American engineers to France during the last winter. This commission studied the reconstruction problems of the devestated region. The talk was illustrated by lantern slides.

Meeting 1044, May 26, 1919.

This was a joint meeting of the Electrical Engineering and the Gas Engineering sections, W. S. of E., and the Chicago section, A. I. E. E. and A. I. & S. E. E. The meeting was attended by 140 members and guests. J. C. Wilson, assistant chief engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis., gave a paper, describing the method of measuring gas electrically, illustrated with lantern slides. The method described is the development of Prof. Thomas' early work; the adaption of familiar principles providing for an accurate measurement of gases in large quantities. B. E. Fernald of Cutler-Hammer Mfg. Co., Milwaukee, Wis., presented a moving picture, illustrating the use of lifting magnets.

Excursion, Saturday, May 10, 1919.

Under the auspices of the Entertainment and Excursion committee an inspection trip was made to the Buffington Plant of the Universal Portland Cement Co. Special cars on the 1:35 Lake Shore train carried 150 members and guests. Representatives of the company presented brief descriptions of the various interesting features, after which the party was divided into groups and escorted through the plant, including the drying kilns, clinker kilns, pulverizers, clinker storage, pulverizing mill, cement storage and shipping departments. Special attention was given to the fuel economizing process. A luncheon was served at the main office and a musical program provided before returning to Chicago.

Book Reviews

SEWAGE DISPOSAL. By Leonard P. Kennicutt, C. E. A. Winslow and R. Winthrop Pratt. Second edition, re-written. 547 pages, 6 by 9 inches. 144 illustrations and diagrams, 136 tables. Bound in cloth. Published by John Wiley & Sons, Inc., New York. Price, $4.00.

Since the appearance of the first edition of this work in 1910 there has been great progress made in the methods of sewage treatment and an understanding of the complex processes involved has made it possible to install plants with every probability of successful operation. One of the most important has been the development of the Activated Sludge Method of Disposal. Details in the various processes, such as fine screening, aeration, grease and nitrogen recovery, and other improvements and refinements made a complete revision of the work necessary. It is fortunate that the same three authors were prepared to bring the work up to date. Measured in space, the revisions means the addition of some 111 pages, with a corresponding increase in illustrations and tables. This is not the whole story, however, as practically every paragraph has been rewritten to conform to the best practice of today.

Considered in the light of a developing science, sewage disposal is subject to still further improvement. Congestion of population in cities and along streams or bodies of water will necessitate improved methods of treatment. It is probable that disposal by dilution will give way to methods which will confine the purification to the immediate limits of the municipality where the sewage originates. It is also probable that more attention will be paid to the commercial value of sewage.

Post-war conditions in every country will make sewage disposal a vital subject to consider, in reconstruction as well as in the utilization of the numerous plants, camps, industrial towns, etc., which have resulted from war activity. This presentation of the principles of sewage treatment will be welcomed by engineers and contractors, physicians and public health workers, and others trained or interested in sanitary engineering or its allied fields.

C. A. M.

AMERICAN HYDRO-ELECTRIC PRACTICE. By William J. Taylor and Daniel H. Braymer. First Edition. 440 pages, 6 by 9 inches, 258 line drawings, many charts, tables and diagrams. Published by McGraw-Hill Book Co., Inc., New York. Price, $5.00.

Only those who have followed carefully the trend of hydro-electric practice can realize the amount of work and the number of plants now in operation. A few monumental structures like the Roosevelt and Keokuk Dams attract attention for their size rather than for their industrial value or as a part of the water power development. Yet these are only two of a large number built in this country, and corresponding numbers of plants have been built abroad where the topography lends itself to this class of development.

To a certain extent the subject has scarcely been touched, but on the other hand there has been a great deal of constructive development in many parts of this country and Canada. As the high voltage at which the current is produced permits its distribution over a radius of 300 to 400 miles, the possibilities in the way of development of the surrounding territory can be readily imagined. It means cheap light, heat and power in places where these utilities are otherwise difficult to obtain, for power, that is, labor, is the expensive part of every industrial enterprise.

Development of the water-power means a conservation of coal and other fuel. Unlike them, the supply of water-power is constantly renewed, and is not subject to exhaustion. Unlike a coal mine or oil well, the hydro-

electric plant increases in value as time goes on. Each new customer means an increased income, up to the limit of the plant to supply the current.

A treatise covering the subject as this one does is a real help to the development of the country. The authors have spared no pains to cover the subject thoroughly from a constructional viewpoint. Some forty large plants are described and illustrated in considerable detail. This detail is of value to the engineer, while still avoiding much of the individual descriptions which might quite properly be included in a magazine article.

Other chapters cover the subjects of General Survey of Water-Power Engineering, Layout and Selection of Plant Equipment, Transmission Line Construction and Operation, Plant, Line and Substation Costs; System Operation and Economics, Special Plant and Line Problems, Data, Reference Tables and System Diagrams.

The compilation of the practical and essential features of design, construction and operation as worked out in many plants and systems, will be of interest and value to plant designers, constructors and operating engineers. The fact that theoretical design is practically eliminated will make it a useful volume to those who are already supplied with the usual text and reference books on dams, plant and equipment from a more specialized standpoint.

C. A. M.

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Fatigue of Metals Under Repeated Stress

By HERBERT F. MOORE,

Research Professor of Engineering Materials, University of Illinois.

Presented April 21, 1919.

THE formulas and methods we commonly use in computing the stresses in structural members and machine parts by no means give a complete statement of the stresses present. They neglect many localized stresses caused by erection methods, by unequal settlement of foundations, and by sudden changes of outline of parts. These localized stresses are, in general, not important in structures subject to steady load or to slight variations of load, or even in structures loaded a few thousand times. They are, however, of great importance in structures and machines subjected to many thousands or millions of repetitions, or, worse still, reversals of loading. From such a localized high stress cracks may spread, causing gradual breakdown of the material and eventual failure. Such a failure is known as a "fatigue" failure.

Fatigue failure of metals is characterized by suddenness and apparent brittleness. A shaft of mild steel, which under a single load would bend double or twist round several times before final failure, under repeated stress may suddenly snap short off with almost no warning, and the fracture frequently appears bright and crystalline. This led to the old theory, now discarded, that under repeated stress metal crystallized and became brittle. The introduction of microscopic examination as an auxiliary to chemical and physical testing of materials soon showed that all metal is crystalline in its structure, and that when metal is over-stressed incipient failure is shown by the appearance of slip lines extending right through crystals, and apparently denoting shearing along planes of weakness within a crystal.* Following the development of these slip lines, and frequently spreading from them, there are developed large cracks, some one of which causes failure of the metal. The development of slip lines is shown in Figs. 1 to 3.

To the designer or to the testing engineer the outstanding characteristic of fatigue failure is its development from some localized bit of structural damage. Dead load failure is a structural breakdown over a considerable portion of the metal; every struc-

*Ewing and Humfrey, "Effect of Strain on the Crystallin Structure of Lead." Phil. Trans. Royal Soc. Vol. 200, p. 241 (1902); Ewing and Rosenhain, "Crystallin Structure of Metals." Phil. Trans. Royal Soc. Vol. 193, p. 353 (1899).

ture and most machine parts are locally overstressed in a hundred places, and so long as the loading is not repeated more than a few thousand times this local overstress does little harm. But when hundreds of thousands of repetitions, or, worse still, reversals, of stress, take place, then each of these little overstressed portions may become a centre of development of structural damage, which may gradually spread until finally the member breaks.

This spreading of structural damage in the form of microscopic cracks explains the suddenness of failure under fatigue. A flat bar of soft steel may be bent double without cracking, but if it be cut

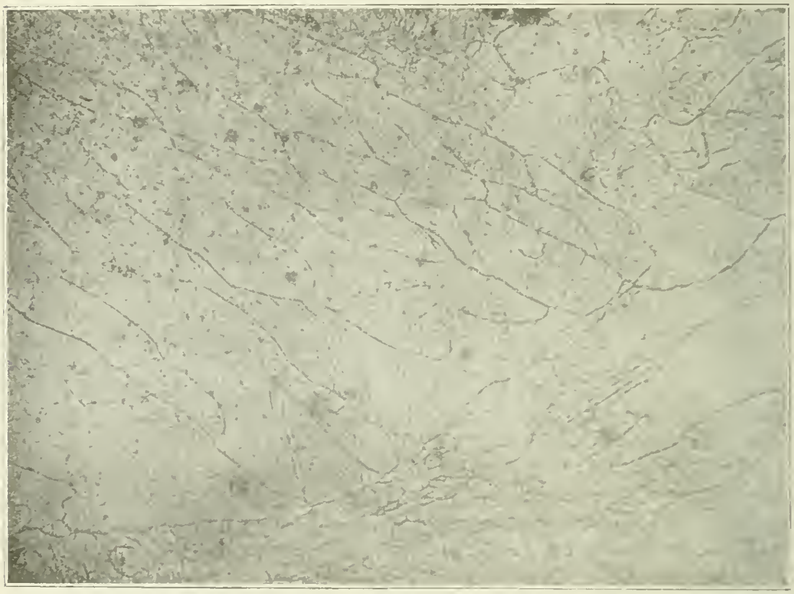

Fig. 1

half across by a fine saw cut and then bent it snaps at the saw cut. The miscroscopic cracks through metal under repeated stress are equivalent to little saw cuts, which gradually join each other; they have very little effect on the general deflection of the metal, but gradually develop localized planes of weakness, along which sudden failure may occur.

The question of greatest interest to engineers, however, is how to choose materials and how to proportion members so that failure by fatigue will *not* occur under service conditions.

One of the most perplexing questions in connection with the fatigue of metals today is the question of a suitable rapid test for fatigue resisting strength. The opinion formerly was common that the determination of the elastic limit furnished such a test; in fact, that within the elastic limit no destructive action took place

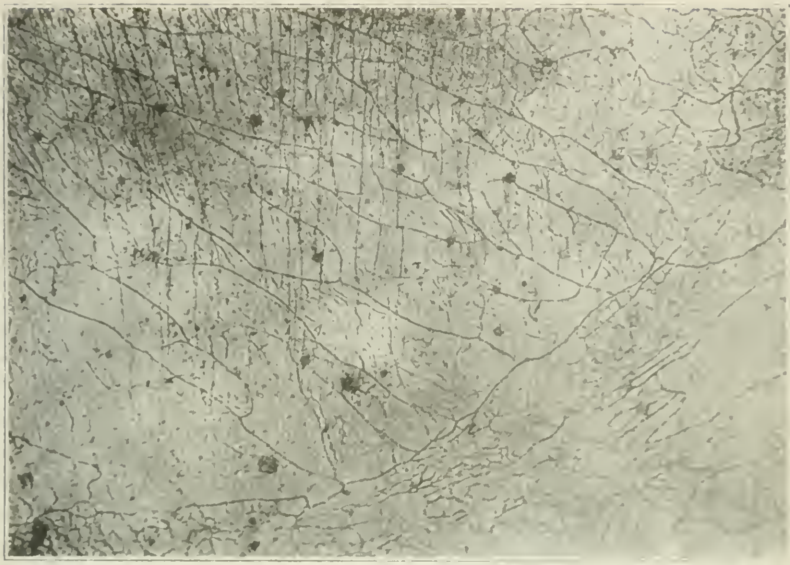

Fig. 2

and the endurance of the piece was infinite. Tests at various laboratories have pretty thoroughly demolished this latter idea and recent tests have thrown great doubt upon the reliability of the

Fig. 3

elastic limit as an index of endurance strength. In the first place, the term elastic limit is rather loosely used today and covers a rather wide range of meaning. In the second place, experimenters in different laboratories using several kinds of machines have repeatedly caused failure of specimens at computed stresses lower than the lowest "elastic limit," as determined by static tests. In 1916 Messrs. Corse and Comstock presented before the American Society for Testing Materials a paper on manganese bronze in which they gave results of static and repeated stress tests of various bronzes, showing that bronze with high static elastic limit sometimes failed under lower repeated stresses than did bronze with a lower elastic limit. Similar results have recently been obtained at the University of Illinois on tests of cold-worked steel and of heat-treated alloy steel.

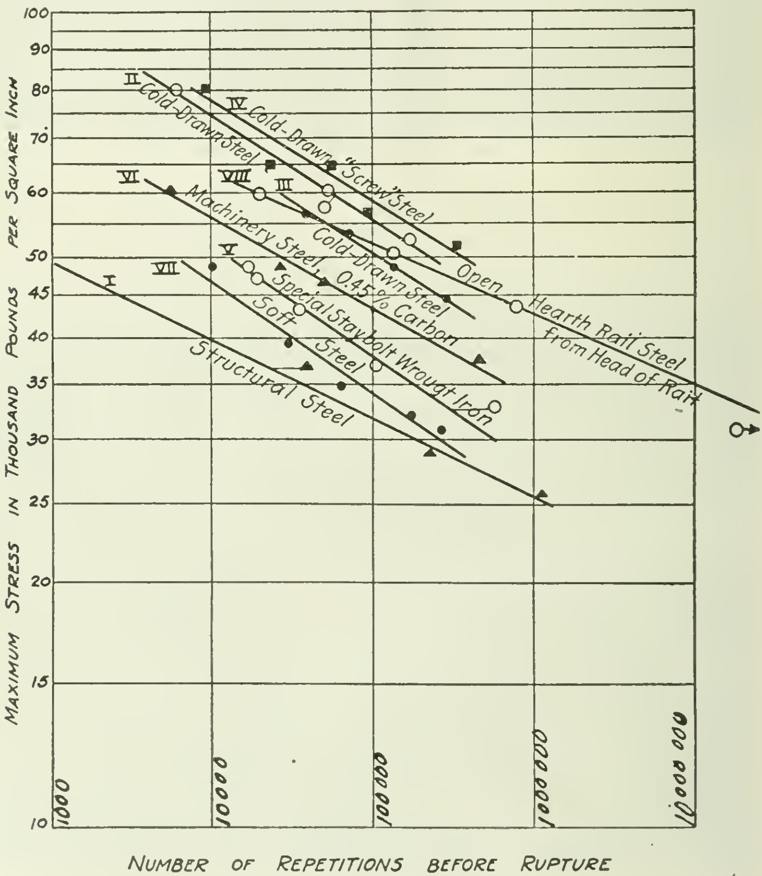

Fig. 4. Endurance Diagram for Various Metals Tested Under Repeated Stress

If a metal has a crystalline structure containing microscopic flaws, the fatigue strength may be low, while the elastic limit as determined by an ordinary tension test may be high. An explanation of the reason why the elastic limit of a metal is not affected appreciably by microscopic flaws is that the elastic limit is determined by the action of the metal over a considerable length—at least two inches of test specimen. The abnormal stretch at a microscopic flaw coerces such a minute portion of this length that it does not appreciably affect the general stretch.

Another test which has been proposed to determine the resistance of materials to fatigue under repeated stress consists in subjecting samples of materials to a comparative small number of violent bends or twists, measuring the amount of the bending or twisting. Such tests have some value as to indicate the ductility and the toughness of the material and might indicate the resistance of materials to a kind of fatigue such as is set up in locomotive staybolts and possibly reveted plates in boilers which are subjected to occasional severe wrenches. It is possible that such a test would be of value in testing material for crankshafts, which are subjected to occasional severe "knocks." This kind of a test does not, however, give great promise as a reliable index of the ability of the material to withstand long-time fatigue under working stress.

It has been proposed to use some standard stress in making fatigue tests of metals—a stress of 38,000 pounds per square inch has been proposed for steel. It is not certain, however, that the relative fatigue strengths would be the same at the arbitrary standard stress as at other stresses. In the writer's opinion the best criterion for fatigue-resistance is found in the endurance diagram, in which fibre stress is plotted as ordinates and numbers of repetitions to produce failure are platted as abscissas. This diagram can be advantageously plotted on logarithmic cross section paper, when the plotted points usually fall fairly closely along straight lines, at least up to 1,000,000 repetitions of stress. Fig. 4 shows several such diagrams. The ordinates of such a stress-endurance diagram show the fatigue strength for any given number of repetitions and the slope of the diagram gives an index of the relative fatigue-resisting strength for high stresses and for low stresses. It should be repeated that some uncertainty exists for the region above four or five millions of repetitions, but this is true for all repeated stress tests. We have very little test data for tests involving more than 5,000,000 repetitions of stress. Examination of samples for flaws by means of etching, and by the use of the microscope is a valuable auxiliary in testing metals for fatigue strength.

A fatigue failure of a machine part may start at a surface irregularity, especially at a sharp, inward-pointing corner, a groove, or even a deep scratch. Polishing the surface of test specimens has been found to increase their resistance to fatigue greatly, especially under low stresses and long time tests. A good smooth surface finish and the use of generous fillets at shoulders are excel-

lent means of insuring relatively high resistance to fatigue. Two excellent examples of this means of increasing resistance to fatigue failure have recently come under the writer's notice. In some tests of the fatigue strength of chrome-nickel steel made in the materials testing laboratory of the University of Illinois by Arthur G. Gehrig it was found that polishing the surface increased the fatigue strength more than did either of two heat treatments, both of which were effective in raising the tensile strength of the material as determined by a testing machine test. A large railroad recently found that fatigue failures of car axles which were not diminished in number by the use of special high strength steel were greatly diminished by making axles with generous fillets at the shoulders, and by using a finer finishing cut over the axle. The user of machinery may well bear in mind that in a machine part every scratch, groove, and shoulder without a generous fillet is a possible neucleus for starting microscopic cracks which may cause failure.

In conclusion, the writer wishes to emphasize the fact that by careful design and selection of materials it is possible to design machine parts and structural members which will withstand the repeated stresses which come on them in their normal lifetime. Bridges are standing today which have endured millions of repetitions of loading without failure; elevated railway structures are standing which have withstood tens of millions of load; shafting is running which has withstood hundreds of millions of repetitions of stress. The possibility of fatigue failure should be recognized by the machine designer and user, and also the fact that by the use of proper working stresses, the choice of proper material, and the proper design of parts reasonable security against fatigue failure can be assured.

DISCUSSION.

Mr. Howard: It is recognized as important to acquire data upon the phases through which steel passes from its primitive state to that of rupture. The phenomenon of flow is displayed by most steels when tested to destruction by loads once applied, or when rupture is accomplished by a few repetitions of stresses. Steels which fail by fatigue, so-called, do not, necessarily, display appreciable permanent elongation. In fractures of steels which occur under service conditions the phenomenon of flow is commonly absent. If an appreciable elongation of the steel is displayed it is quite obvious that an overload has been received. A decided permanent set in itself affords sufficient evidence upon this point. The behavior of the micro-constituents under over-straining loads, however, is a matter of deep interest. The microscope has not cleared up the matter of fatigue fractures where no appreciable flow occurs but constitutes, nevertheless, a step in the right direction.

Under repeated alternate stresses steel is ruptured not only without appreciable permanent elongation, but may result from stresses which in magnitude are only a fraction of the elastic limit

of the steel. The deepest interest attaches to how this result comes about; by what means the approach to rupture under such circumstances may be recognized. From the results of laboratory tests it is known that hundreds of millions of repetitions of certain moderate stresses may be received before the steel ruptures, while a few hundred thousand or a much lower number of repetitions of more severe stresses will cause rupture. In each case, however, there is the same outward manifestation, the steel breaks short and brittle. There is no display of ductility. This is the type of failure which is encountered under service conditions. It is in fact the usual type of service fractures.

In addressing ourselves to this phase of the problem of how steel fails it will be borne in mind that overstraining loads modify the relations of the elastic limits of tension and of compression; that the modulus of elasticity is at least temporarily impaired; that internal strains are generally set up and there is reason for believing that a permanent change in the density of the steel occurs. The temporary change in density while the steel is being strained is expressed by Poisson's ratio. It is not known with what degree of uniformity these changes are distributed in the mass of the metal, how influenced by chemical composition, or modified by structural or metallographic states.

The phenomenon of flow, or permanent set in steel, is incident to the shape of the member, also whether stressed in one direction, or whether there are simultaneous stresses in more than one direction. In the softer grades of steel a local elongation of several hundred per cent is possible, but to give consideration to these features at this time would be a departure from the subject of fatigue of steels in which rupture commonly takes place with entire absence of such display.

Microscopic evidence has been lacking concerning the recognition of a state of internal strain, whether of tension or compression; neither has it been made clear whether there are detectable microscopic changes which precede rupture in the vast number of service fractures of steel. A most interesting field of inquiry is presented in the investigation of the phases through which steel passes in fatigue fractures, and such aid as may come from the microscope in the solution of this problem will be an important contribution.

Question: I would like to inquire to what extent those small cracks can be met by annealing. In what stage must the annealing be applied in order to be of any service to correct the cracks? I know of one concern using a good many cranes and they used to anneal the chains every year. I know of a certain railroad company that took out their track pins when they had run so many thousand miles and annealed them.

Mr. Moore: I am afraid I cannot answer the questions concerning the annealing of the crane chains and track pins. I suppose that if these small slip lines only had developed and no large cracks

developed from them, annealing would remedy the trouble. That is one of the several hundred points upon which I hope some day to get direct experimental evidence. I think the annealing would remedy the small slip lines, but probably not the large cracks.

Question: With regard to the annealing of the crane chains I might say our practice is to anneal all crane chains once a week. That brings it down to a very short period of time.

Question: The stresses were very heavy stresses, were they not?

Mr. Moore: In order to show the action within the limits of the motion picture we had to run very heavy stresses, well beyond the elastic limits of the steel. In running quantitative tests in some machines the stresses are measured and in others the deformations are measured. Our usual practice in the university laboratories is to measure what I call nominal or computed stresses, probably of little irregularities on the surface, and quite possibly of irregularities inside the steel. Of course the little microscopic stresses we cannot measure, but when we get quantitative stresses we do measure them.

Mr. Howard: In regard to your remarks on annealing, I have made some tests along about 1883 or 1885 on some iron bars which showed at that time a tensile strength of about 52,000 or 53,000 pounds per square inch. From tests at different intervals since that time I have found there was a considerable increase in the tensile strength, which went on for as long as I have observed it, which is a matter of ten or fifteen years. At the last tests which were made the tensile strength, with relation to the primitive area of the bar, had reached about 68,000 pounds per square inch, but the bar was so brittle it failed, with a crystalline fracture in lieu of a fine fibrous appearance. In this instance annealing the iron brought it back to substantially its primitive state of toughness and tensile strength. I have carefully retained a bar which I hope some day to make further tests upon. It is now something over thirty years since it was originally tested, and I hope some day to be able to say what its tensile properties are.

Question: How is the testing and annealing of chains done?

R. J. Young: I think the practice has been in the Chicago District not to anneal the chains. We found by a careful study that if the annealing was not done by an expert and done in annealing furnaces, the chain was not materially made safer. In fact, usually it was worse than before it was annealed. It may not be brought to the proper temperature and will then be too soft, or it may be heated to too high a temperature and we have the same trouble—a proper crystallization or re-construction has not taken place.

Question: How can you determine when a chain is to be scrapped?

Mr. Young: The way we have taken care of that is to scrap practically all our chains and use wire rope. We determine how

to scrap that by the broken strands. That will show the danger point much quicker than the chain will.

Member: We don't always get all of our expert information from the laboratory. An old blacksmith once said that the way to see whether a chain was any good or not was to put it into the furnace and heat it to a thorough red heat and slowly draw it out of the furnace under a stream of water. He said if you watched it closely, and your eyes were good, it would show a darkening spot where there were any cracks in the metal, and certainly it would show any dangerous crack. That method of testing a chain was used by the chain makers before we had testing machines to pull them apart, and after all I don't know but what it may be nearly as good as the one they use now.

To go a little further, unfortunately I have to carry on an argument against this fatigue. I suppose one-tenth of what I have said about steel has been in explaining away this crystallization idea. The idea that steel fatigues in crystallizing is one that is settled in the minds of so many people, it seems more firmly lodged than any other, and it has been a test for me to get by in certain cases. They always came back at me that you could break a chain with a tack hammer if you hammered long enough on it.

I was peeved here a good many years ago when they tore down that beautiful suspension bridge at Minneapolis. That bridge had been there a good many years, but when they took that wire out and made fatigue tests on it, it didn't show any fatigue—it showed the wire was just as good as the day they put it there.

We had a very high viaduct in Pennsylvania, over three hundred feet high, perhaps the highest, earliest iron structure built at the time. Of course when it was built they didn't anticipate the change in loading, but when they did change the loads and began to run heavier trains over it they made fatigue tests on the structure; the tests showed no defects; the viaduct was as good so far as the fatigue tests were concerned as when it was put up.

The Iron Age reported a chain bridge in Massachusetts built away back in colonial days, and that chain suspension bridge has been in service longer than our United States Government. Fatigue tests were made on that chain to find out whether it had been weakened by its long service. The report was that it had not been. I used those three examples in my argument on crystallization and here comes this man and upsets the whole game; he unseats what we have all thought was a safe thing. I hope he will go farther and find the ultimate limit and put us back in a state of composure as to what fatigue really is.

Mr. Moore: First I would like to ask one question. In the tests you have just spoken of, were there fatigue tests made of those samples or were they ordinary retention tests?

Member: I think they were retention tests.

Mr. Moore: That does not show whether a metal is fatigued or not; we have no warning of impending failure in fatigue tests.

Mr. Howard at the Watertown Arsenal has conducted one of the most important series, or really several of the most important series of fatigue tests ever conducted anywhere. Sudden fracture is one of the bad things about fatigue, and the ordinary tension test does not show it. The mere fact that we test a piece of metal out of a bridge or a wire rope and get good ordinary testing machinery results is not particularly assuring. This fact, however, is, that while any stress, if repeated often enough, may fracture a member, yet the ordinary working stresses on steel have to be repeated a great many hundreds of millions of times before the steel is fractured. For example a piece of ordinary structural steel at the University of Illinois laboratory was subjected to 526,000,000 reversals of stress, and the change was so slight that I'm quite sure the janitor stepped on the weights or that some accidental cause might be blamed for the failure. But it did stand 526,000,000 reversals of stress without failure. We can be reasonably sure that we can design structures which will withstand hundreds of millions of repetitions of stress without failure.

Civil engineering structures such as bridges and building, while we say they have lasted for fifty or one hundred years, have not had so many changes of stresses. The Nubriport Bridge would not have a full load every time a team went over it. It would have in that location perhaps at most a hundred loads a day, which would be 36,500 stresses a year, or 365,000 in ten years, or about 7,500,000 in two hundred years. That is not very many repetitions. Until we get above a million we don't have very many repetitions. Until we get up to ten million we are not outside the limit. Take, for example, a very busy railroad bridge, and say a life of thirty years. It would hardly get more than a couple of million repetitions of stress. Civil engineering structures rarely get to the point where fatigue is a determining factor. But I feel sure there is such a thing. In structural practice I don't believe it is very often a factor; in machine practice, of course, it does come in.

Industrial Personnel Relations

By A. H. Young,
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Presented March 24, 1919.

WHEN I was invited to talk on this subject your chairman told me I was free to express any thought I might have as to the position of the engineer on this industrial personnel problem. I have beheld with a great deal of alarm the appropriation of all things referring to the personnel by some so-called engineers. I have had a feeling that personnel problems are not directly within the province of the engineer in the field as we know them, or an exact science, as it were. Some of them are subject to reduction as an exact science; some of them are hardly chargeable as anything but variables.

Recently in a convention of industrial engineers, one speaker analyzed personnel problems into twenty-four different factors, each one of which might be approached from three different angles, and no single factor that he named was an exact science, or charted as anything but a variable in any equation. Among others he mentioned safety, employment management, working conditions, hours, wages, sanitation, medical service, and so on down through a list of twenty-four.

Let us take up the first two—safety and employment management. All of you have witnessed the birth and the growth and the final fulfillment of the safety movement. It was only about twelve years ago, that the first organized safety work was undertaken. It is generally credited to the South Chicago plant of the Illinois Steel Company, and began before I had anything to do with it out there. At that plant some genius suddenly discovered that accidents were not necessary and could be prevented. Before that time, it was taken as a matter of fact that accident and the killing of men went hand in hand with the making of steel. In 1905 we killed 47 men in our plant. About once a week the old "Black Maria," as we used to call it, came up to the hospital and took away some workman who had been killed. The genius had a hard time getting a start, but once the interest was aroused in the movement, he had all kinds of backing. The practical unanimity of the organization for conducting the campaign is the best practical proof of the wisdom of the original plan.

The first attack of course was purely mechanical—safe-guarding gears, removing projecting set screws, putting railings on platforms, etc. Several hundred thousand dollars were spent at this time in this particular plant on that program. The results were disappointing. Accidents had not decreased over twenty per cent at the end of the first three years. But by an analysis of the accidents it was discovered that carelessness was really the major cause; that

it was a question of education, to make the habitually careless man one who was careful, or perhaps I should say, to make the man who was careless habitually careful.

You all know that the perfectly natural way to cross a street is just as a chicken does, to look neither to the right or the left, but go right across the street. It is only by a process of education that you pause at the curb and look to see whether the way is clear, cross to the center, look both ways again and cross to the other side. That was the problem that had to be met in safety engineering. It was an intensely human problem. It brought into play from the laboratory of the safety engineers the movie, the bulletin boards, noon-day meetings, safety buttons, prizes for safety suggestions, etc. Finally it was realized that in order to make a man think safety all the time you would have to carry safety into the home. It was the safety inspectors and supervisors of the industrial plants that first started our public safety campaigns, so the children might carry home with them the safety problems. Just how successful that plan has been you can see instantly from the figures of any one of a thousand different concerns. The particular plant of the Illinois Steel Company shows that accidents decreased from the old number of 47 down to 7 in 1913, so you can see that all the money that was spent was worth while.

This startling result was made known after an experience of several years, and not before. It was not the incentive for the program. And the company had actually made money in doing it. Not only have they been successful from a humanitarian standpoint, but they have made money. By multiplying the average number of men each year by that rate you would then have the theoretical number of accidents, which would have occurred during the year if we had not bettered our 1906 figures. Multiplying those accidents by the average cost of settling the case each year will give you the average cost of settling the cases. Substract from that the actual money spent in settling the cases of accidents which did occur and you will then have the gross saving. And there was charged up against this amount every item, too; the hospital cost, the time of workmen's committees, the cost of all safeguards, every dollar was charged against it. The result, after subtracting the charges, was a sum almost exactly equivalent to the charges. In other words, although this marvelous result from the humanitarian standpoint had been obtained, the company found they had a one hundred per cent dividend on the outlay.

These figures have been confirmed in all the general plants of the United States Steel Corporation. In their latest bulletin they show since 1906 a prevention of, roughly speaking, twenty-five thousand serious or fatal accidents. They rate a serious accident any accident which causes loss of time of thirty-five days or more, or results in a permanent disability, such as the loss of an eye or a thumb.

Just now labor turn-over is a very fashionable term. If we

take this little by-product of twenty-five thousand serious and fatal accidents prevented, it is fair to assume that a man absent for that long must be replaced in the organization. They have estimated that it costs anywhere from forty to two hundred dollars to replace that man and train a new man on the job. It is safe to assume that those in the steel business are not the lowest paid or the least expensive to replace, and those are conservative figures. If you multiply that twenty-five thousand by say an average of one hundred dollars, the cost of replacing them, you will see what it amounts to.

But another result was had. A few years ago the steel corporation was standing suit for dismemberment. A number of men, old employes of the plant, went before the master-in-chancery and begged that the corporation be not dissolved, and that there be not a return to the old days of cut-throat competition. In those days there was no safety first movement. Those men actually, of their own volition, and without any urging on the part of the management, appeared before the master-in-chancery and asked that the corporation be not dissolved, because it might interfere with the efficiency of the safety movement. Is it not safe to say the managers of the corporation were pleased with that little action on the part of their employes?

Getting into the question of the employment management, there seems to be an inclination to say you have to be born with the zodiac in a certain position to be able to handle it successfully. With your pardon for being personal, let me illustrate with one reference what employment management means. I went to work in a mill when I was about thirteen years old. My father spoke to the master mechanic and said that Art was going to finish school next Friday and wanted to go to work to earn some money during vacation, and was there a place for him to work. Sure there was a place, send Art out Monday morning. I was there. The gateman knew I was coming. He sent me down to the shop. I went down there and the master mechanic wasn't there, but he had left word that I was coming, so I went out to see the engineer. He wanted to know if I knew anything about oiling. I was thirteen years old and I knew everything about everything. He turned me over to his assistant. The assistant showed me where the cylinder oil and the beeswax were, and that was all the instruction I got. In those days we oiled all during the day. After I had been on the job about three days we had a fire, and it came from an overheated bearing. I discovered that bearing at the time of the fire. It seems that a pulley that was at the end of the shaft that I thought was over-hung, actually was hung between two bearings, and I never got around to that other side. By the time the boss got down there I was working away with a piece of wire cleaning it out; I said it had been plugged up, and I was cleaning it out, and I got away with it that time, but the state factory inspector came

through shortly and discovered that I was under fourteen and I was fired.

I still recall the shaky ladder with which I was allowed to take my course and climb to a highly revolving shaft, with every coupling having projecting set screws and projecting bolts to oil that machinery. Mine was probably the most dangerous of any job in the shop. Of course, I came in under a little different conditions. The gate man knew me and expected me. If a stranger had gone on the job and there had been a vacancy as oiler, probably the assistant engineer would have come to the gate and he would look the bunch over and if he saw any little ambitious looking fellow like me there just a little crook of his finger would have put the man on the pay roll. There was no more selection at that time, or any more instruction.

Contrast this experience with what happens today in a modern employment department,—a centralized employment office in any respectable industry. The employment manager is selected, as a rule, because of his personality. He must be a man of enough engaging personality to be able to talk to men and get men to talk to him. In most plants he is rated on personality a good deal more than fifty per cent. Much more is he rated on personality than on his technical training. He has a staff, including interpreters. And the gang doesn't congregate at the gate and wait for the foreman to come along and make a haphazard selection,—no. The superintendent calls up the employment agent and he says, "I need one oiler." I don't believe that the employment agent should finally select the man; his performance of work on the job is the test, and not any quizzing that you give him at the employment office. It will only serve to get rid of the manifestly undesirable applicants. The chap is invited to sit opposite the interviewer at his desk and a careful history of his former experience is drawn out. If he hasn't worked as a machinist in the plants in which he says he has, that becomes a matter of knowledge when the replies to the requests for information begin to come back. If he happens to be a foreigner he is quizzed in his own language. He is told something of the plant policies. That is the most important part of the employment work. It begins with the employment management. The reputation that the management has is ultimately that through which the employment manager must work. If the owners of the business have a reputation for square dealing, of stability, and right human relations, then the employment manager has an easy task. The man is told about the promotional opportunities; that it is the policy of this plant to promote from the ranks and that they will maintain in their records carefully the application he has made out and keep it on file, so that while the job they are putting him at at that time may not be the one that he wants, if later that job that he does want turns up and a vacancy exists there, he will be given a

promotional opportunity instead of that job which he wants being filled by an outsider.

He is told that the policy of the management is such that they don't allow their foremen to indiscriminately discharge a man, but that the foreman can recommend discharge, and that if this chap doesn't cut the mustard he may be given one more chance. At the time his foreman turns him in he will be quizzed, and given a chance to tell his side of the story, and at least he will be given one more chance. He is probably given a book of rules printed in his own language outlining the dangers of his occupation. That book is preferably written by the men in the plant, and he is told at the time that the book was written by those men, and that it is only necessary for him to go to the nearest oldtimer and talk with him about those rules and he will get what he is after.

Then on the employment record card is carefully entered all the facts with reference to his personal history which are available; his age, whether or not he is married, his place of birth, the number of dependents, with particular detail the prior experience, and his ambition as to the job he wants; possibly a statement as to his military service; some statement as to whom might be notified in case of sickness, etc., all this for statistical purposes later.

It is coming to the point now that employment men are taking three and a half hours and three and a half days to put a man on the job rather than hiring a man in three and a half minutes. Men are beginning to talk about how long it takes to put a man to work, rather than how quickly they can do it. This chap, having been given this lecture, in some plants is now taken to a lecture hall and shown movies. In the plants of the Dupont Company he is shown movies that explain the whole process of the plant in which he is going to work. Then he is taken by a personal guide to the gate of the plant which he will afterwards use, which is always the one nearest to his place of employment. He is shown how to get there from the car lines; possibly in the meantime the employment agent has assisted him in getting a boarding house; if he has stated that he is married, it is possible that he has been shown a map, and where in the vicinity of the plant he can locate to advantage. Then he is conducted from the gate to his place of work over the proper and the safe route. On the way is pointed out to him the danger signs and what they mean, the general lockers and wash and toilet rooms, the plant restaurant, the general store room, and just a brief sketch of where the particularly important parts of the plant are located. Then he is personally introduced to his foreman by name. I have stood in the employment office and quizzed a man returning to work who wanted a job and said to him, "How long did you work here?" "Six months." "What was the name of your foreman?" "I don't know; we called him 'Slim.'" A man had worked in the plant directly under a fellow human for six months, the man who was his immediate superior, and he didn't even know the name of that superior. Now that man is introduced personally to the foreman.

The last thing that the personal guide who is doing all this sightseeing trip says is, "Mr. Foreman, won't you please give this man some special instruction in the particular hazards of his own individual job?" Then it is the duty of the foreman or someone in his gang delegated for that purpose, to take the man and show him what his dangers are, and to introduce him by name to some of the fellows alongside whom he will have to work; some fellows who have something of the gift of the teacher and can talk to him and tell him about his work. Particularly is he told about the job he is going to perform, what relation it bears to that moving picture he saw back in the other room, and makes him a part of that institution for producing a certain thing.

It doesn't take any analysis to show how much more apt you are to get a man to stick on his job and to feel that he has become a part of your organization if he is introduced in that manner, as contrasted with putting him on the pay roll, with no introduction to the plant or the men.

The chairman has referred to Bolshevism. It would be idle to deny there is a real danger there. I think it is easily perceptible that the relatons between employer and employe can influence that directly. There are a good many guesses as to just why Bolshevism exists. Probably when Russian history is written it will be considered that the reason for the movement was that the men were not in on the "know." Possibly a benevolent despotism has raised their system to a better plane than they themselves under a democratic form of government could have reached, but certainly the citizenship of Russia didn't know how well off they were. They were never taken into confidence. You are only mildly interested in what somebody else is doing for you. You are vitally interested in what you are doing yourself. Apply that, then, to our personnel relations.

Supposing you go down all through the thirty or forty-eight or one hundred and twenty-four component parts that make up personnel relations. You hire the plant doctor; you start physical examination; you start an employment record where you are going to have this man's physical condition analyzed and recorded, and you are going to give him a job which his physical condition fits him for, and if anybody ever tries to transfer him from that job your doctor has got to be in on the say so to know whether the new job is favorable to his condition. You have fine toilet-rooms, locker-rooms, wash-rooms, etc. All this you are doing for the man. You may be spending thousands of dollars, all with the idea that you want your employes a little bit better cared for than anybody else's. Your wages may be the highest in your particular industry, —but always out in the shop is the fellow who is ready to say they ought to be a little bit higher; that your concern is making millions and if you split up all around the wages would be doubled. Your men are just mildly interested. I consider that the job John D. Rockefeller has done in the Colorado iron and steel mines in the

introduction of industrial democracy one of the biggest things of the times. We are beginning to let our employes in on the "know." The Youngstown Steel, The Midvale, and dozens of others are adopting and advancing a plan of industrial democracy.

We are staging something of the kind just now. The determination of the policy of the company with reference to wages, hours, sanitation and all similar matters are determined by a Works Council, composed one half of representatives elected by the employes, and no man rating as assistant foreman or higher is permitted to vote on that council. They must be American citizens, have been with the plant one year, and twenty-one years of age or over. The other fifty per cent is composed of representatives appointed by the management, the superintendent, staff, etc. Each votes as a unit. The majority of either side determines the majority of the whole side. They must agree in the Works Council or they cannot function and finally determine action within the Works Council. In case of a disagreement it is in order to re-open the discussion and propose an alternative or compromise resolution. If, after such a complete discussion, they are still in a deadlock and voting one vote for and one vote against, then the matter must be referred to the president of the company. It was thought that in such a case of an absolute failure of the local management to agree with the workmen, that the highest executive officer of the company should pass upon it. Therefore, within ten days after that deadlock is announced and it is submitted to the president, he must propose a plan acceptable to them or propose an immediate arbitration before a disinterested arbitrator, in which case they each choose one, and if the two can agree on the point or points at issue, then the matter is settled right there; but if they cannot agree, then those two choose a third. In each case the arbitrator chosen must be disinterested. Their final agreement is binding on both parties, and retroactive. As a second operation, the president may throw the matter before the general council of employe representatives of the plants generally. With the Harvester Company we have some twenty in this country and Canada. They may be used as an arbitration body, and the president can summon a general council, each sending two representatives, or one representative for each thousand employes. They then meet as a general council and the matter is put up before them. If they can come to an agreement a settlement is made, and it is binding all the way down the line; if not, the matter may go to arbitration. In any case of arbitration it is optional, it must be agreed upon by both parties. The employes might take a stand and say we are going to have what we have asked for or we will strike. In such a case it is manifestly of no avail to force an arbitration; they wouldn't be bound by it. It is also reasonable that there may arise questions which the management would not submit to an arbitration. Then it lies with the president and a majority of the representatives to agree and select their arbitrators.

The plan provides for the recall of employe representatives. At any time a man is unsatisfactory to the members of his own voting division as a representative, one third of them, petitioning, can arrange for a recall ballot. If a majority vote for his recall he is out of the ballot. The plan provides distinctly that the determination of policies be given to the employes to participate in on a straight fifty per cent basis, but the policy having been so determined, the management will execute that policy. If there is a question as to the proper manner of execution that again lies with the Works Council. The management shares with the men the legislative and judicial functions of the government, but reserves to itself entirely the executive operation of the plant. The plan provides that before any matters shall be brought before the Works Council they shall be presented to the superintendent or the secretary. If, after presentation to the superintendent, the employe or the representative is not satisfied with the proposed adjudication of the matter, then it may come before the Works Council, and not before. In other words, the foreman and the superintendent stand as they do now in direct relationship to their men, with this exception.

When we first put in centralizing employment offices and the foremen found that their action was reviewable and that it wasn't arbitrary, there was the greatest improvement in the art of firing among our foremen that we have ever known. So, too, it is probable that foremen and superintendents will exercise all due discretion in settling grievances that come to them, knowing that their judgment is reviewable by the Works Council. The plan is only applied at plants which accept it by a majority vote by secret ballot.

You will be interested to know that when the plan was first offered it was accepted at all our plants with the exception of three. Those are located in the very center of Chicago's west side. I am not prepared to state just why the plan failed in acceptance there. In those plants, the foreign born employes comprise more than seventy per cent of all of the personnel. We printed our plan only in English, as a proper step, we thought, in our Americanization campaigns. As a result many did not understand it and went to outsiders. There was a meeting under not exactly neutral influences the night before the election. We made no positive campaign to sell the plan. Our foremen were instructed to answer any questions. It was simply a dignified presentation of something over and above that which they now have. Our placards showed the man how to vote for it and how to vote against it. The only plea was that we hadn't made it quite clear in one particular. Our ballots read "For adoption," and "against adoption." Had we printed them "Yes" or "No," the men would have better understood what they were voting for and which way they were voting. Many advisors told our employes that came to them asking for information as to how to vote, to vote on the bottom line. The words "against adop-

tion" didn't mean anything to them and of course they did as they were told. The day after the election they found themselves in the small minority, with probably a better understanding of the plan. The old employes wanted it accepted, and they immediately circularized a petition. In all of those plants petitions were signed for the adoption of the plan by from seventy-five to eighty per cent of all of the employes. Of course we knew that every employe wanted his name to be on there for the boss to see. They immediately petitioned for another ballot. We told them they could hold it themselves, but only under the condition that a timekeeper was present to see that none voted except those that were qualified. In two of the plants they have re-balloted and accepted the plan by a vote of two to one. So, virtually, we have today all the plants operating under that plan. We don't think we have solved the question entirely. We think that we have a medium of contact. We think that through these groups of employe representatives we will be able to educate the employes to some of the problems of management, and we know we will get a direct reaction as to the attitude of the men. We know they are going to realize what the safety movement costs us and what we make out of it, and what they gain out of it.

We are not going to put on a periodic physical examination of our employes unless they want it themselves. We expect through them to let individuals know the result of that physical examination. We expect to adjust our wages and hours with a correct knowledge on the part of our employes as to where our wages and our stand with regard to other people in other industries compare, and also as to the situation in the local region generally, and to educate them as to some of our problems in securing the distribution of our products.

This is an experiment. I wish that I might tell you of a record of accomplishment and be able better to answer your questions. It is purely conjecture up to the present time, however, except for this: This afternoon at our plant works we had the first meeting of the Works Council. We wanted to put the proposition on about one hundred per cent munitions work this fall, and therefore we rushed through last summer our manufacturing program of the parts with which that plant is particularly engaged. We got our regular manufacturing program out of the way and doubled the force so we might take on the gas shells which Kaiser Bill wanted. Now we find ourselves with nothing to do, and we have to temporarily reduce the manufacturing program there. We put it right up to these fellows this afternoon as to just what we were up against—we let them know it all. We have been working a five-day week of nine hours, and half a day on Saturday of five hours, paying time and a half for the ninth hour each day. These fellows came right back with a proposition of a five day week of eight hours each, and would we be willing to pay them instead of the half-hour overtime, a quarter of an hour on an eight-hour

day? They said, "If you propose to do this on a fifty-fifty basis, that is our idea of fifty-fifty; we give up an hour; you would be gaining an hour and a half's time, and we think the fifty-fifty proposition is to split that difference." Of course the management is more than pleased with such a proposition as that, and we depend upon these representatives to sell it to the men. The meeting was wholly pleasant. The men came through in a surprising manner and their reception of our proposition could not have been more favorable, nor could their comeback have been squarer than it was. There was none of this business of quitting or standing out for the full half hour's overtime. It was a very straight comeback, and the company was more than pleased with it.

That is the only experience rating we have thus far on the plant, but I think we have the answer. That is bound to have its effect nationally. We are confronted, as I see it, with a distinct menace of Bolshevism. It is largely because we have never taken the laboring class into our confidence. We have never explained it to them or taken them into our meetings, and I believe that in the Harvester company we are going, through this plan, to so set the current of their thoughts on constructive work. You have to play up the controversial features. But, as a matter of fact, our expectations are that this plan,—this Works Council,—will deal largely with a constructive thought, the safety movement, the fellowship movement, the recreation, and we will have enough of that business for them to set the current of their thoughts, so, when we have controversial matters, we will be able to deal with them at a "round table" and in conferences that will be beneficial to both the men and the company. We believe we can get that distribution in conference which will prevent our being separated in our plant and possibly deal with our adversaries.

DISCUSSION.

Chairman: I feel that we have been highly entertained and materially benefitted from an educational point of view by Mr. Young's able talk, and we sincerely thank him for the information that he has given us. Now before throwing the subject of the evening open to general discussion, I would like to call upon a few men who have had experience along this line for just a few remarks. I would like first to call upon Mr. Tyler of the Montgomery Ward & Co.

Mr. Tyler: Our problem is different from most of you gentlemen here I believe, in that we have more of a commercial institution than an industrial one. The prime importance of properly shaping the mental attitude of an applicant the first day he comes into the institution is recognized by our house. We have gone the limit in establishing an attractive room where we receive these prospective candidates for positions, and have provided them with adequate resting places until their turn comes at the application tables. They are provided with pen and ink and a comfortable

chair. We follow the plan that has been outlined in testing out an applicant. We go even farther than that in our plant, because we have some positions that we hire for directly. I might say here, though, that we have in the past year limited them, and it is now limited to five in the case of men, and in the case of women we have reduced them from twenty-seven or twenty-eight to about twelve. We test out for accuracy and speed in different ways and then pass them along to the plant instruction after they have passed the physician examination.

This plant instruction we are going the limit on in our establishment. We have thought so highly of it that we have set up the machinery, as it were, that the applicant is going to work with. Where we deal with a wrapper, or a checker, or an order filler he actually is instructed right there and then in the work that he is to perform. We take the time to determine before he leaves the room whether he is going to be able to perform his duties or not.

We then see that he has been properly introduced, as has been explained heretofore, to the head of the department, because the mental attitude can be so shaped in loyalty to the plant. He can be told all of the inside working, and if he is properly handled in the first forty-eight hours he is at your plant you can do more with him than you could a year ago in six months. We take the classes of supervisors which you gentlemen are familiar with. We have these people come before the plant instructor or his supervisors and they are tested out every so often to see whether they are measuring up to the standards of the house. If not, they are recommended for some other position. We insist that they get down close to the employe, and the house as a whole has gone so far as to say to the executives of the establishments that they shall be the last out at night, because we want them to know the personal relation of the employe. The mail order business has been put right up to the heads of the business. His contact with the employe must be such that he knows just exactly what the financial condition of that employe is; whether his family is well and healthy and what he needs and what he has to do to be a satisfied employe.

Chairman: The Republic Flow Meters Company has installed a plan recently of coöperation between the management and the employes, and I would like to have Mr. Cunningham, the president, explain that plan briefly to us.

Mr. Cunningham: The following address made by our vice-president to his employes last summer when we put this plan into effect fully explains it:

"It is my desire now to place before you a purely commercial proposition or offer, whereby we, the working members of this company, are to share in the financial interests of the company and to participate in the profits that may be derived from our work.

"This proposition is the result of a careful study of the now prevailing relations, or rather antagonism, between the so-called Labor and Capital factions. And before we go any further I wish

to state that in my opinion this antagonism is not between Labor and Capital as such, but between two distinct classes of the same Labor faction. This antagonism is between the class of laborers who assume the responsibility of results obtained from their work, and the other class of laborers who do not care what becomes of the work after they are paid for the day or hour.

"We often hear this term Capital, and in our imagination we picture this term as the monster of the age fighting against us, while if we care to analyze the matter we find that Capital itself is entirely dormant. All that the stockholder, representing Capital, can do, if he is not actively engaged in the business as a responsible laborer, is to wait patiently for the dividends to come, and if they do not, he may sooner go to church and pray for them than go to the company and ask for them.

"The business of the company is regulated not by the Capital, but by the class of laborers who are responsible for the results of their work and as I said before, all the so-called labor troubles are due to antagonism or misunderstanding between the responsible class of laborers and the less fortunate laborers who are not given the chance to assume the responsibility for the ultimate results of their work. Our problem is, therefore, to remove this antagonism or misunderstanding between the various members of the company, and the solution would be to have all laborers or working members in the same class and responsible for their work. There is no secret in the motive or reason for this responsibility and interest in the work. We all know why some laborers are of the responsible class and some are not. We all know that those laborers who are directly or indirectly interested financially in the proceeds of the concern will always be of the class that are responsible for the result of their work.

"It is evident, therefore, that in order to fix this responsibility on all the working members of the company it is necessary that they should be interested in the welfare of the company in one way or another; that is, the arrangement should be such that the ultimate welfare of the company should result in the increased welfare of the individual laborer or worker.

"In my recent visit to the East I had a chance to study the matter and I purposely approached many authorities to advise me how some profit-sharing proposition with employes might be accomplished. Some of them came out with a pessimistic answer stating that 'There is no use trying, you can never get the laborer to take interest in the ultimate success of the business. It is immaterial what you do, what bonuses you give or increases you make, the laborers will always have that antagonistic feeling against the so-called Capital.' Some were more optimistic and their advice was to make the laborers invest their money and become stockholders in the business. Now this solution of having the laborers become stockholders and actually own the business is well and good, but how can it be obtained? Suppose the laborers have no

money to invest in the company's stock; you have to get money outside to run the business; what can you do then?

"The solution I arrived at, and which was favorably passed on by our directors for the immediate adoption in the business, is to create a so-called labor stock dividend; that is, the adoption of a rule whereby all the working members of the company should be paid the same interest or dividend on their production or earnings as the stockholders of the Company are paid an interest or dividend on the amount of capital invested in the business.

"This labor stock dividend is by no means a bonus or welfare proposition of any kind. It is a just and righteous business proposition and one that will always lead to success. It is just and righteous because I sincerely believe that when profits are made by the company each laborer is entitled to a dividend or interest on his earnings or production, the same as the stockholder is entitled to a dividend or interest on his capital. On the other hand, it will always lead to success because it will establish the interest of the working members of the company and this interest, as you well know, is the basis of prosperity and success.

"The regulations of the labor stock dividend as adopted by the directors of the company is based on the accumulative monthly earnings for the year, or the half yearly services of each individual worker. All present employes of the company in any capacity whatsoever, from the president down to the errand boy or girl, are termed the "Workers of the Company." Each worker is to receive a dividend from the earnings of the company equal to the amount received by a stockholder who possesses paid up stock certificates equal in amount to the half yearly earnings or wages of the given worker.

"To take a specific example: A man earns twenty-five dollars per week. At the end of the first month his productive investment is $100, while the average during the month is one-half of that, or $50. At the end of the second month the total production amounts to $200, and the average is $100 for two months. At the end of the year the total production amounts to $1,200, and the average is $600 for twelve months. To be exact, the labor dividends would have to be computed as they accumulate during the year, but for the convenience of accounting, it was decided to distribute them equally over the whole year.

"When new employes are taken into the services of the company they are not to participate in the dividends for the first six months, which is considered a trial period. If they are retained with the company after this period, they are to receive equal dividends based upon their half yearly earnings with the company.

"The dividends, of course, are to be distributed at the same rate and at the same time as dividends are distributed to the stockholders of the company. Necessarily, dividends will be paid only to such employes who are in the service of the company at the time the dividends are declared.

"I wish to repeat that these dividends are not a bonus depending upon the good will or desire of the administration. They represent simply and purely the formation of a partnership between the stockholders of the company supplying the capital and the workers of the company supplying the necessary labor. It is to be hoped that eventually the workers of the company will be the stockholders as well, so that they will receive dividends both on the capital and the productive investment with the company.

"As to the future success of the company, it stands to reason that since the prosperity of a concern depends upon the intelligence and care of its laborers or workers for the interest of the concern, therefore, this prosperity will necessarily increase with the increase of the number of workers who care for the ultimate success of their work. As a consequence the maximum prosperity will be reached when all the workers or laborers of the concern will care intelligently for the successful result of their work as well as for the ultimate success of the concern."

This plan was just put into effect last summer, but we think it is going to work out very well. In fact, I don't think anyone could hire any of our employes away from us. We treat them as capital interests. We are trying to combine the labor and capital idea. Each man can figure just exactly what his return will be. He can figure at the end of the year, or at the quarterly period when our dividends are disbursed, just what amount he is going to get. You take a man who is working on a lathe. He has a thousand pieces to turn out of a certain article. If a piece spoils he knows that is going to eat into the profits of the company, and that it will also reduce his share of those profits. He takes a great deal of interest in trying to get one thousand perfect pieces out. We noticed right away that the laborers and machinists were very much more careful than they had been before. They are trying to make us pay eight or ten or twelve per cent. The idea that they are really investors in the capital of the company is going to work out very well I am sure.

Chairman: You are all very much interested in the plan that has just been outlined, and I believe that if we want any further details we can get them from Mr. Cunningham or from Mr. Pritzlaff, the vice-president.

Mr. Bibbens: I came to listen and not to talk, but I cannot help but recall, after listening to Mr. Young's address, a meeting of the two presidents of two of the societies represented by this gathering tonight at which I had the pleasure of being present, and they both had next to their heart the question of capital and labor and the position which the engineer should take in the settlement of that problem. These two gentlemen spent nearly all the afternoon discussing it from its various aspects, with the object of endeavoring to ascertain whether it was feasible to start a campaign among the engineering societies of the country to see if the engineer could be brought into the problem as a vital part of the

solution. The decision has not yet been made, but I can assure you that two of the three presidents of these societies have this question close at heart.

Mr. Young mentioned the Rockefeller movement in Colorado. In 1915 I had the pleasure of meeting McKenzie King, who is now the commissioner of labor, in the bottom of the Grand Canyon. It wasn't a very good place to talk shop, but during our long ride Mr. King cut loose. It was the first time I knew he was the man who had been very deeply instrumental in the settlement of that Colorado question. Later he sent me a little pamphlet describing that settlement. I have never forgotten that personality, and I can realize fully well what an important part the personality plays, and how far the engineer must depart from his slide rule and his book of logarithms to be able to function properly. In Denver the Denver Street Railways used to have much trouble with their men. They gradually found a way to cover up that trouble when it appeared, and lately the company has come under the management of a comparatively young man. He established a Monday noon roundtable for his superintendents and his foremen. They all get together, not in a ramshackle eating-place, but in the club. They are all taken into the Denver Athletic Club and they feel that little courtesy. In a good natured way one man is played against another, all jovially, and when a man falls down he acknowledges it, and they all have a good laugh over it, and the manager says that if nobody else can do it he will jump in and try to do it himself. Of course, he never has to. This young man established a meeting hall, a gymnasium, a restroom and a forum for discussions, also a brotherhood of railway men. He is a member of it and he knows practically all the men on the system personally and they exchange courtesies on the street. When the question of a raise in fare and wages came up he didn't try to settle it in his mahogany lined office, but he went down to this forum with both arms bulging with company books and he spread the books before the men and asked them before they made any decision to appoint a committee and meet with him and he would show them every mystery there was inside the company. That committee was appointed, but about that time a labor organizer from Detroit got on the ground and by misrepresentations succeeded in winning some of the men into returning an adverse vote. Without calling these men down at all this manager gave them a little further light and asked them to investigate themselves, with the result that within a week the men themselves repudiated their former decision and ran the labor agitators out of town, and they are now a happy company.

Speaking of accidents here in Chicago, I wonder how many of you realize the tremendous reductions in accidents on our surface street railways. A comparison was made sometime ago of the accident situation before and after the reconstruction of 1907, and you will find a record of that study if you care to look for

it in the annual reports of the board of supervising engineers. The reductions are tremendous, especially since the introduction of the pre-pay cars and the closed doors and automatic control. The reduction is something like seventy-five per cent below that which would have obtained with the old type of transportation that existed before the reconstruction period.

Mr. Bailey: I have a great deal to say, but, personally, I draw a humorous side of the industrial manager problem. When Mr. Young spoke of the industrial manager glorying in the fact that he spent three and a half hours upon an applicant, I was thinking of a manager spending a day with each individual applicant, and which one of probably one hundred different applications he was going to fill with that one particular man. Of course, that is an exceptional condition, we all know that. I feel, however, that we have all learned a great deal from Mr. Young's talk, and I know we are all interested in the development of the Harvester scheme. I am sure that all of us that have to handle men will be interested in that. It all goes back to the fundamental principle of having a common meeting ground and a common interest. The fellow that shares your troubles with you has your side of the argument much better than the fellow who is only a part of the machine, without any knowledge of its internal working. The prime object of all these developments and organizations is the establishment of a common meeting ground where each one can understand the other fellow's troubles and can appreciate the other fellow's viewpoint.

Chairman: I will now throw the meeting open to a general discussion. Before doing so I would like to make this announcement. The Harvester Company has prepared a little booklet which describes in detail the Harvester Industrial Council which Mr. Young referred to, and I know he would be very glad to furnish a copy of this booklet to anybody who really wants to study into the scheme a little further. If anybody would like to ask Mr. Young any questions on this subject, or carry the discussion further, I know Mr. Young would be glad to answer them.

Mr. Norwood: It seems to me that this problem that has been worked out by the larger organizations is taking the place that has been handled by labor unionism for a good many years past. As an employer of union labor I can see the handwriting on the wall as to what the large user of labor is coming to. In other words, the labor organization has got a common meeting ground where the men can discuss their troubles, but at which the employer is not represented. He doesn't get word unless there is some vital trouble. The point I would like to have Mr. Young explain a little further is along those lines. I have been reading that the English manufacturers are adopting programs along those lines, and I did not realize that the English employer of labor allowed them to have anything to do with the establishment of wages. I would like to have Mr. Young explain that point a little

further. My personal opinion is that if the employers of labor years ago had established this common meeting ground that a lot of trouble would have been avoided between the organized labor and their employers.

Mr. Young: I think we could spend a whole evening on just that subject. I think a good deal of odium is attached to the employer of today for his failure to recognize some of the constructive possibilities of the national union. The most significant difficulty is that they are organized industrially and they incorporate into one body all of the employes of the concern instead of dealing with them by crafts and trades only. When a committee is appointed or selected or elected then you have a group which represents your own employes, and which you cannot consistently fail to meet. The Hartley Commission reports in England have brought about a reconstruction of the old trade union movement exactly along those lines. They have recommended a revamping of union labor within itself, that the unions be organized industrially, that is to include all the employes of an industry. The result would be something like this. We might have in this country in the iron and steel business, the locals in each plant. Then there would be the general Illinois Council of the iron and steel industry. Then there might be the National Iron and Steel Industrial Conference. In addition to that we might have geographical divisions, that is, for the quarries and other industries not large enough to be organized in themselves, or by themselves. There would be the Illinois Supervisory Council and the Western, and possibly the National. And then we would have, instead of crafts, unions constituted of all the employes of an industry. Just now, with the industrial unrest, a good many employers who before had not a good word to say for the American Federation of Labor, are seeking with growing openness to bolster it up. Their fear is that the body is not strong enough to hold together the trade unions.

I had the pleasure of talking with Mr. Byron of Boston last Friday morning just as he was about to sail for England. He is openly working for a greater recognition of the American Federation of Labor, and its now termed "conservative operations" as contrasted with radicalism of the Bolshevik. I think that the day of collective labor is here. I don't see how any employer can refuse the right of his men to bargain collectively. Just what is the effect of these conferences with the employes themselves is shown very directly in the coal, fuel and iron situation, where the greatest experience record is had. They have been going some three years. I have been told that originally the plan was put in in gold mining camps where they were one hundred per cent organized. Since its introduction the membership in the Western Federation of Miners has steadily decreased. They have simply failed to renew their dues, and twice the federation has extended the period of time it would carry a man for non-payment of mem-

bership without forfeiture. They made a final show-down last April. The men found they could get more through this industrial democracy form of committee work than they could through the trade unions, and therefore that there was no need of them carrying on the monthly dues and strike benefits, etc. In some of those camps where the membership was fully one hundred per cent, when fully organized, it has been stated that the membership is now less than forty-five per cent, and not active at all, at that.

Mr. Norwood: I had the pleasure the other day of calling on a personnel department office of the army and I was very much interested and enlightened as to what the army really had obtained. They had divided the applicants. A man was called and tested out for a chauffeur and an electrician, or whatever his trade, and the men were graded, and the percentages taken from this test were really startling. I believe something like fifteen per cent were experts, forty per cent were journeymen, and the balance were nobody. That was the result, taking the case of the electricians. I think they have some tests there for chauffeurs which were really remarkable. A man who probably had been driving a truck for somebody made an application as a truck driver. He was shown the tests and immediately he said, "I can't do it." There is a little plate laid out there of what he is to do, and some of them were smart enough to say immediately they couldn't do it, and others who were put to the test fell down, and the percentages were along the lines I have just mentioned. It seems to me that in the employment in these large establishments, especially where they go into the labor end where any skill at all is required, if they had some means of giving even a slight test it would certainly save the foremen on the job, who really employ these men, a lot of trouble and time later on, because it is getting to the point where it is a difficult matter to fire a man, even after he has been employed.

Inland Waterway Transportation

Theodore Brent,
Traffic Manager, Mississippi-Warrier Waterways Barge Commission, United States Railroad Administration, New Orleans.

Presented May 19, 1919.

WE assume as a premise what we believe to be a fact, namely, that freight can be transported by water in well designed equipment upon proper channels much more cheaply than it can be hauled over the best railroads. Our own internal freight rate situation is a standing example of the cheapness of water carriage.

The country at large has for years had the benefit of the economies of water transportation. Though the public has accepted and enjoyed these economies as a matter of course and has fought for their continuance, they are being gradually neutralized, for they have been uneconomic in their application and therefore easily assailable. Our competitive system has for years required of the railroads that they transport for the public at large at the equivalent of the cost of water service. Wherever a rail carrier found itself in competition with a waterway which had been or might possibly be used to haul freight, the public demanded of the railroad rates comparable with the lowest charge the waterway might conceivably make, and the rail carrier's interest has generally been conceived to be in the direction of making such rates and eliminating the menace of a real water competitor. As a result, the boat line as a competitor of the railroad has died. The live boat lines exist today only as connections or feeders of the railroads.

There are innumerable illustrations of this general statement. Probably the most comprehensive example is our socalled transcontinental rate system—the rate fabric at which is transported the enormous tonnage moving between the Atlantic watershed and the Pacific Coast. These rates, from the date of completion of the first through railroad between San Francisco and New Orleans have been dominated by the Morgan Line. This line, half steamship, half rail, and requiring one, but more frequently two transshipments, has kept its rates so regulated as to maintain a constant threat against ambitious all-water projects and, because of the economics of this route, it has always been able to set the pace for the all-rail lines.

Just prior to the war, when the water lines through the Panama Canal were beginning to get a good foothold, the Morgan Line petitioned the Interstate Commerce Commission for permission to meet this coast-to-coast water competition, by its rail-and-water route through Galveston. Inasmuch as they desired to meet the low through rates and leave the intermediate rates high, they

had to prove to the commission that their carriage of this through freight would yield some return and not prove a burden on their otherwise high rated traffic.

They showed that the water lines were carrying beans, canned goods, barley, asphaltum and wine from San Francisco to New York at approximately six dollars per ton. They calculated that with their superior service they could charge eight dollars per ton and compete. They said they could not afford to haul this traffic all rail across the continent at eight dollars a ton against the then existing rail rate of $15 per ton, but maintained that they could do it by the use of their rail-and-water service.

The rail mileage from San Francisco to Galveston is approximately 2,200 miles and the water mileage thence to New York the equivalent of 1,900 land miles. They carefully calculated the cost of train and station service properly chargeable to this movement between San Francisco and Galveston, assuming the position that no other costs need be considered as the road must run anyway and pay its fixed charges and maintenance whether they hauled this freight or not, and they showed that their out-of-pocket costs of the rail haul were around $5 per ton. They showed from their books that the average cost of the entire water operation was $2 per ton, and allowing the fixed cost of the transfer there was still a margin of profit in the through traffic at $8 per ton if they were not required to carry intermediate business at the same rate. The commission granted the plea, evidently being convinced of the correctness of both the figures and the reasoning.

To the interested observer, there were two very significant points brought out and passed upon in this case. First, it was shown that a first class water service was being performed by the Southern Pacific Company at less than half the cost of its train and station service on its rail lines, making no allowance for the physical and financial maintenance of the rail property. Secondly, the commission held, by inference at least, what in fact is the contemplation of the law, that a rail carrier owes no duty whatsoever to a competing water carrier, except to maintain a monopoly of public carriage at whatever rates may be dictated by water competition, down to the point where there is no longer sufficient return to pay the actual out-of-pocket costs of the particular rail operation under review.

These rate-making principles, rather more than the inherent inefficiency of the water carrier, have been responsible for the gradual elimination of the steamboat from our internal public carriage.

Such a system is essentially uneconomic because it must be maintained by at least quasi-public servants by means of a charging system which assesses against a part of the public inordinately high rates in order that the carrier make its rates below the fair cost of rail service wherever necessary to retain the revenues of carriage between the more favored communities.

There is no more glaring illustration of the inequalities of

this system than the rates between New York and Chicago and up and down our own Mississippi Valley. Both to the eastward and to the southward the rates which Chicago has for years enjoyed have been made to meet one or another form of water competition, real or potential. Hardly a schedule remains which has not under repeated reviews been admitted to be subnormal and justified only on the ground that if advanced the traffic would necessarily be shared by and with some water service. Now, a natural separation is taking place. Rail costs have greatly increased. Coal, before the war worth a dollar a ton at the mine, costs the railroads $2.50 to $3. Rails are no longer $27 per ton, but $60. The increases in wages have been given wide publicity. A twenty-five per cent increase in rates has proved wholly inadequate. The public will hardly stand for another flat advance of twenty-five per cent. There is nothing left but to raise the many depressed spots in the rate fabric to the new high level of the plain, and that is just what is being done.

Chicago, having been probably the most widely favored, must be prepared for the greatest advances. She must be prepared to pay for the cost of rail transportation, not water service. To get the economics of water service she must be prepared to use the lakes and rivers. Even they cannot now exist at some of the low rates she still enjoys by rail. Good water projects have several very strong points of advantage,—the cost of maintenance of the routes is nominal; the operations are peculiarly well adapted to the most economical use of crude oil, the only fuel which has or can soon approach pre-war costs; the operations are capable of almost indefinite expansion without finding a large amount of new capital for permanent way; equipment and power can be provided more cheaply than an equivalent carrying capacity of cars and locomotives.

Let me say, however, that this all pre-supposes good permanent channels and a good regular tonnage which can be carried substantially the year round without serious interruption.

No single steam railroad without important feeders ever escaped receivership for considerable periods in this country. So with a waterway. Its business can no longer be local, for our merchandising today operates on too broad lines for such a waterway to serve any useful purpose.

The successful waterway must, first, have a good channel of large capacity, must be well equipped, and, above all, it must be so integrated and correlated with the railroad system of its territory as to interchange business at all its ports and, through rail carriers, reach out laterally in all directions to the extent of its capacity to serve the public at a saving.

When the war brought internal chaos to the rail carriers and a law had to be framed which would eliminate the difficulties inherent in competitive operation and insure a return to bond and shareholders during the war, Congress authorized the President to com-

mence the rehabilitation of available inland waterways at the same time he advanced the Federal funds to rebuild and newly equip the railroads.

The first project recommended for such treatment by the Committee on Inland Waterways was the lower Mississippi River. There exists a good dependable channel between St. Louis and New Orleans of nine feet at dead low water. It is well marked and is maintained constantly for purposes other than navigation. The crossings or sand bars which form at time of high water are systematically removed as the flood crest runs off, and by keeping the channel confined in its customary place erosion and levee destruction are minimized.

The project was approved in July, 1918, and the federal manager instructed to get into operation all available existing equipment with minimum delay and to plan and construct a permanent fleet capable of carrying at least 1,000,000 tons annually between the two ports.

Operations were commenced in September, 1918, with a small fleet of some 30 barges of 500 tons each, and five tow boats of limited power. This fleet has now been in operation eight months, giving one sailing a week from each terminal and carrying substantially 2,500 tons down stream and 1,500 tons up. The service has been maintained through the period of the lowest and the highest water. The operations have been maintained with fair regularity. The only interruption was four weeks of ice interference in the upper river, during which time the service was maintained from Cairo southward.

A recent tow southward made the run from St. Louis in four days and eighteen hours. The customary time southbound is six days. With present tow boats it is taking fifteen to eighteen days up-stream, for the pressure of business offers constant temptation to overload the tow boats.

At the commencement of operations, when there were only local rates in effect, the most of the southbound loading was bulk grain and much of the equipment was returned light. Since late January, however, the Railroad Administration has caused the rail carriers to join the barge line in a full basis of joint rates on all classes and commodities between the states of Illinois, Wisconsin, Minnesota, Iowa and Missouri on the one hand and New Orleans on the other.

These rates operate through St. Louis, where trans-shipment between the river and rail carrier is performed. They offer the public a saving of about twenty per cent as against the all rail rates, and out of them the rail carrier gets the same revenue it would were the shipment forwarded all rail, the barge line making the shrinkage out of its proportion of the rate. This saving to the merchants and consumers of sugar in Chicago for example amounts to nine cents per hundred pounds.

Since the inauguration of these joint rates high grade mer-

chandise for domestic and export movement is gradually taking the place of bulk grain southward, until now about a third of the cargo is made up of freight paying from \$4 to \$8 per ton against \$2.40 per ton for grain. Northward the barges are loaded to capacity with sugar which pays around \$5 per ton, while the line is having to shut out much coffee, rice, molasses, alcohol as well as such low grade bulk commodities as nitrate, sisal, sulphur, etc.

The overhead expense is necessarily out of all proportion to the size of the operation, because of the limited capacity of the available fleet, but each month has shown a substantial lessening of the disparity between earnings and costs. No demonstration of the proper cost of the operation is possible with the present fleet. At present there are building for the permanent operation of the line forty steel barges of 2,000 tons dead weight carrying capacity each, and six twin screw tunnel type tow boats of 2,000 indicated horsepower each.

These tow boats are designed to propel a tow of five of these barges down-stream fully loaded with ten thousand tons of revenue freight and to bring back in the same equipment 5,000 tons at not less than five miles per hour up-stream.

The present boats are deficient in power and enormously wasteful of fuel. The new tows of nearly four times the present maximum capacity will be handled with the same crews and with but slightly greater fuel consumption. With the same organization as at present the line will be able to transport 1,500,000 tons of freight annually. All indications point to a very economical operation and the eventual reflection of even greater savings to the public through joint rates.

Through bills of lading in connection with the rail carriers are operated to all interior destinations. On exports, Chicago merchants may today secure these savings in rates through the operation of joint service under through bills of lading direct from Chicago via rail, river and ocean to all destinations served by regular liners operating from the port of New Orleans.

Chicago's pre-eminence has always been maintained by her enjoyment of low water freights to the eastward. The operation of the Panama Canal must inevitably change the trend of much of our traffic southward rather than eastward, because of the shortening of the water routes to the Orient through the Gulf, and because even the rail routes to the Gulf are much more cheaply operated than the routes over the Alleghenies.

But when it is recalled that freight may be floated from Chicago to the Gulf by the provision of the Illinois Waterway now under contemplation, it seems almost incredible that there can be real hesitation to put the project in motion under the existing situation in the matter of rail freight rates.

The Federal Government has spent \$300,000,000 to complete the Panama Canal, and as it stands no other single act of Govern-

ment has been so potent to neutralize Chicago's advantage of central location and draw trade and industry to the seaboard.

Chicago cannot be both central market and dominate the export trade at seaboard ocean rates. But hitherto her great advantage has been her location upon the lakes and her cheap transport to and from the East. That route, however, will always require trans-shipment.

If, however, by the investment of $20,000,000 Chicago can secure a water route over which a tow boat with a crew of twenty men can take down to tidewater in ten days 10,000 tons of freight and in twenty to twenty-five days bring back 5,000 tons, both operations without trans-shipment or other incidental expense, it would seem too directly of advantage to require long debate. A state which willingly authorized $60,000,000 of bonds to commence a system of hard roads within its borders can hardly fail to appreciate the value of a system of waterways which will open up the heart of the state to the cheapest possible communication with the sea.

A deep ship channel would be a waste, for there are no compensating benefits commensurate with its cost. There is no great gain in sending small lake vessels down to the sea. But a waterway which will permit of barges of maximum size to take advantage of the existing channel in the lower Mississippi and come on to Chicago and land their cargo alongside the industries as lake freight is today received will prove most valuable to Chicago's commerce.

DISCUSSION.

Professor Moulton: My viewpoint is not so much opposite as it is a viewpoint which is designed to show what are the basic factors in the problem as presented by Mr. Brent. In my judgment, the fundamental premise put down by Mr. Brent and by all other waterway advocates is an unproved premise. That premise is that water transportation is cheaper than transportation by rail.

It should be clearly understood that I am not referring to transportation on the ocean. There is no question about the cheapness of transportation there, because there is no opposition. Also there is no question with reference to Mr. Brent's judgment concerning the trans-continental rate system. I also wish to make it clear there is no question concerning the cheapness of transportation on the Great Lakes. The Great Lakes were always there; they did not have to be created. What I have to say will be confined to internal waterway transportation, where you have to build your waterway before you can transport your goods.

I have said that I do not believe that the contention that the waterway transportation is cheaper than railway transportation is correct. In the first place, I want to show you what is involved in the cost of water transportation. We will take a concrete example. The state of New York has been spending more than

$150,000,000 on the improvement and enlargement of the Erie Canal. Bonds have been issued which they have sold to the people of the state of New York at four per cent. The annual interest charge for capital alone on the capital invested in the Erie Canal will be approximately six million dollars per year. The people of the state of New York are going to have to pay six million dollars annually on this waterway. I have no doubt at all that on a toll-free waterway, after it has been created, your boat carriers can move freight between given points more cheaply than can the railroads between the same given points. I think that is an established proposition, and one that no one will question. But, in addition to those direct haulage costs, before you can find out what that transportation costs the people of the state of New York, you have to add to that direct haulage cost the six million dollars annually of interest on the fixed capital involved. You have to add to that the maintenance charge. Mr. Brent has told you the maintenance charge is merely nominal. That would depend upon a large number of factors. In most cases experience has proved that the maintenance costs are indeed very heavy.

Take an example. On the Manchester Ship Canal, which is about thirty-five and one-half miles in length, and fed by little rivers —we would call them brooks over here—the cost of dredging alone is six thousand dollars per mile annually. In connection with our own Mississipi River the engineers tell us that the cost of dredging, not to take into consideration all the other maintenance charges that would have to be met, would be extremely heavy.

It has been the experience the world over in connection with water transportation that the maintenance charges have been rather large. I have tried to indicate thus far the basic principle in cost; that there is that haulage rate which merely covers the expenses on the operation of the boat plus the fixed charges on the boat itself, but over and above that is the social cost, which is paid for out of the taxes.

I am going to pass from the consideration of that principle to the experience of Germany with water transportation. Most of you doubtless believe that Germany has proved water transportation cheaper than rail transportation. However, this is a mistaken opinion, and I am going to give you the reasons why we have been misled with reference to conditions regarding water transportation in Germany. I have made an investigation of all the water projects in Germany, and in that investigation I followed this principle: I took the rates charged first by the canal boats. Then I figured what the overhead expense on the fixed capital invested in those waterways was, and I found out how much that would amount to each year when apportioned over the amount of traffic carried by each water route. In Germany I found that the rates on the railroads, fixed by the Government, were high enough to yield a substantial profit. I found that the rates on the

waterways were always fixed so low that there was a heavy definite deficit annually.

The German Government was in the habit of quoting the rates on the waterways, where they had a big deficit each year, and comparing those with the rates on the railroads and saying, "See how much cheaper it is to carry goods on the waterways," when, as a matter of fact, they were taking the profits earned from the railroad operation to meet the deficit on the waterway operation. Figuring the costs, overhead as well as direct haulage, on every one of the German waterways, with the single exception of the Rhine River, the cost of transportation by waterways was substantially higher in all cases, in most cases two or three times as high as it was by rail. The River Rhine was an exception, due to the fact that this river was like our own Great Lakes, a ready made waterway. It was always there, it did not have to be built, and its operation was continuous throughout almost all of the year. Fed by the melting snows of the Alps there was a steady water supply all summer, and they never had any floods such as we have upon our own rivers. Under those very favorable circustances, including all the costs, I think the Rhine River was successful, but no other waterway in Germany was successfully operated.

If that is true, you say, "Why did the Germans develop their waterways?" I succeeded in finding, eventually, the answer to that question, and I was informed by the director of roads and bridges of France, one of France's greatest statesmen and one of the most eminent economists in Europe, who has agreed absolutely with my own conclusions with reference to the costs. I asked him why it was that the German Government went ahead with this problem of waterways the way they did, and he said, "The German Kaiser had become convinced that Germany's future depended upon the development of Germany's ocean power, and the German Kaiser was under the impression—a wrong impression, by the way—that in order to have ocean transportation it was necessary also to have inland water transportation, quite ignoring the fact that you can have ocean transportation even if you bring your traffic to the ocean ports by rail. Since he had that notion he put through the German waterway program. In 1899 they had up for consideration in Prussia the building of some canals to connect the Rhine River with the Elbe, cutting east and west, running across all those waterways that flow into the North Sea. The upper house in Germany voted down those bills on the ground that water transportation was not economically advantageous to Germany. The German Kaiser immediately removed the twenty members of the Reichstag from office who had voted against this measure, and appointed twenty more in their place who would vote for the measure. That is all a matter of historical record and has been published in different places many times. Having done that he established a waterways department in connection with a department of public works. The duty of that department was to prove

to the German people that waterways were successful and economical. They proved it by quoting rates on waterways that were very low as compared with the rates on the railroads, and neglected to point out that the waterways showed a deficit each year, while the railroads showed a dividend on the money invested. They carried on an expensive propaganda there which promoted the idea that Germany owed her industrial greatness to her transportation system on the water, which theory is entirely fallacious. We have quoted that German situation for an indefinite number of years without ever making an attempt to find out whether it was true or false.

So much for the German waterway system. Now with reference to one or two local projects in the United States. The first is the Missouri River project. I happen to know the statistics of cost and operation there better than I do that of some of the other routes. About four years ago Lieutenant-Colonel Dekine of the U. S. Army Engineers reported that, in his judgment, any further improvement of the Missouri River from Kansas City to St. Louis was a mere waste of the public funds and that the project ought to be abandoned at once. A meeting was called to consider the economic feasibility of that project. I made a very careful investigation of all the factors involved in it. The situation was this: The army engineers concluded that the project could be completed at the cost mentioned. But the difficulty lay in getting sufficient traffic to meet the interest on that twenty millions of dollars invested in the project, and to meet those maintenance costs. Lieutenant-Colonel DeKine was a scientific engineer and he fairly raised the question in this way: "Will there be savings enough in the twenty per cent reduction in freight rates to warrant our expending twenty millions of dollars on this project, and, in addition, paying six hundred thousand dollars a year in maintenance charges?" He came to the conclusion that it would be an absolute waste of the Government's money. I made an investigation of the probable traffic and I put their own figures and subjected them to analysis. As the water rates were to be twenty per cent lower than the freight rates, I found that in order to effect savings equal to the interest upon the twenty millions of dollars, plus the six hundred thousand dollars annually on maintenance, they would have to get more freight than moved over all the railroads between Kansas City and St. Louis. They would have to have four million tons of freight moving annually in order to effect a saving sufficient to meet the cost of interest and the maintenance charges. Only three million tons of freight at that time were moving over four roads between Kansas City and St. Louis, in both directions.

They called a meeting in St. Louis and they had the waterway advocates from all over the Mississippi Valley present. They did not permit anybody to testify who was in any sense opposed to indiscriminate expenditures upon waterways. As a result of that meeting, presenting evidence which did not go to the heart of the

problem at all, the decision was overruled and they decided to go ahead with the project. That is the way we have entered upon our waterway development in this country. We have gone ahead and spent the money, and then hoped against hope that if we didn't charge any tolls to cover these fixed expenses that somehow or other, out of the lessened transportation rates we would be able to get our money back, and in not one single instance where there is an internal canal to be built or a river to be canalized at any cost, have we ever gotten back enough to cover those costs in recent times. I think the announcement and evidence on that is absolutely conclusive. When I went abroad to make this investigation I was under the impression that water transportation in Europe was successful. I will admit that. This Illinois project was voted in Illinois in 1908, and I voted for it, as most of you gentlemen undoubtedly did on the general assumption that the railroads were probably resorting to unfair methods of competition—which they probably did—and that they were making enormous profits, and I thought probably this waterway project was a step in the right direction. I didn't know much about it, and neither did you. It happened that I was asked to make an investigation of some subject in pursuance of the requirements for a higher degree, and I thought I would go into an analysis of the waterway question as one of the best subjects I could pick out. My general conclusion at that time was that I would find most waterways were successful; that there might possibly be certain cases where the traffic available would be insufficient to make it a reasonable project, but that those cases would be very few. But I found that absolutely nowhere had any adequate attention been given to the problem of the original cost of construction and the interest charges on that, which the people always pay. The assumption always seems to be that if the Government does it that somehow or other it gets done for nothing. We have learned something about paying for taxes during the war, and I hope in the future we will recognize that when the government spends the money somebody foots the bill.

After finding that the arguments advanced did not stand the test of reason, I decided I would have to go abroad and study the conditions there. Before I went my general opinion was that probably European waterways were successful, but I imagined that there might be varying conditions over there and that they were different from those prevailing in this country, and that it might be worth while to present an analysis of the varying conditions. Nobody was any more surprised than I was to find what the cold statistics of the inclusive cost of water transportation showed. It was only when I was told by the eminent French economist and statesman what was really back of the scenes in Germany that I got at the inside of the question.

With reference to our own local project I am going to say only a little. The thing has gone through, but I think we ought

to face two or three factors in connection with this local project. If it does not materialize we ought to know some of the reasons why it failed, so we won't blame it all to politics. There has never been any adequate consideration of the probable development of traffic on this local project. There is one possibility of agricultural products, but it is the experience all over the world that agricultural products are not advantageously moved by water, and this has been proved out in Germany. Germany makes no attempt to use her waterways for agricultural produce except where it is brought in at the great ports of the country and can be moved inland by water. The Germans say that agriculture is a de-centralized industry and the trans-shipping cost more than offsets any advantage that the waterways might possibly have. That is their definite national policy. All over the world that same thing is true, so far as collecting agricultural produce from a wide agricultural area is concerned. This also is true, that unless a waterway has easy access to raw materials, mainly iron and coal, it never has any chance for developing large enough volume of traffic to really pay for itself. Let's ask ourselves there whether on this Illinois project we have got the coal. We have not got the iron, but have we got the coal? There is a possibility, of course, that that coal might be brought in from the Illinois mines to Chicago by water. But I want to point out to you first, that the waterway doesn't go right to the coal mines, so you see it has to be brought from the mines themselves to the waterway by rail, reloaded on the boat and brought to Chicago. Then what happens when it gets to Chicago? Can it be unloaded right at the doors of the factories? It cannot. We must remember that the railroads, with their spur lines, go to every part of the city of Chicago. Mr. Tunnell pointed that out years ago in the report of the Chicago Harbor Commission. London, Berlin and Paris have had the same experience. Every great industrial city in the world has had that same experience, that when it comes to unloading the coal it is very advantageous to have your spur line that will run to the back door of the establishment and save the haulage cost. If it can be shown that the rates on the waterway, when you add to those rates on the waterway the cost of haulage a long distance by truck in the city, the cost of haulage by rail from the mines to the waterway, the cost of trans-shipment there, and then, of course, our cost in interest upon that twenty million dollars investment—if it can be shown after all those things are added to the mere cost of haulage over the waterway that the State of Illinois or the city of Chicago is going to get its coal more cheaply delivered to the factories in Chicago than it can be by the railways, then I would be favorably disposed to this waterway. But there has been no attempt even to analyze the figures, and I am inclined to believe that the cost by water, including all those extras, would be greater than it is by rail.

Another feature might enter into the discussion here. We

are very much interested at the present time in the development of trade with South America, and you might raise the question, "Wouldn't a through waterway from Chicago to the Gulf of Mexico prove a tremendous advantage?" That is possible. There is one important consideration which we need to bear in mind in connection with this, however, and that is this: This particular water route is going to be only eight or nine feet in depth and boats which take this down from here to the Gulf would not be able to cross the Gulf of Mexico and go down the west coast of South America. You would have to trans-ship it at New Orleans. The question has to be raised there of including that cost of trans-shipment, and as to whether, after the addition of that additional cost, the traffic that would be secured would pay for itself. It may be that in that particular case you would have traffic which could be advantageously carried by water.

In regard to the project of dredging the channel, I should certainly feel that a project of 24 feet in depth, or even 14 feet, would be open to serious question on account of the cost of maintenance of a channel of that depth. I should say every attempt should be made to carry all we can at the present depth of eight or nine feet. I think we ought to experiment a little with a waterway of that kind before going to enormous expense in building deeper channels.

One factor I have overlooked is the water power aspect and the reclamation of lands along the banks of rivers. I believe this project can be justified only on the ground that the water power there developed will more than offset the transportation advantages. I doubt if there is anybody in the state of Illinois who at the present time knows whether the amount of water power that can be developed and sold profitably will be sufficient to warrant these other considerations. What I have been pleading for is a face to face consideration of all of the factors that enter into the problem. You can reclaim these low lying lands along the river without building a fourteen foot channel or without giving any attention whatever, if you choose to do so, to the transportation considerations. Thus far in our history we have always assumed that the cost of water transportation would pay for itself as a transportation project and that these other things are clear velvet. We should find out what the cost of transportation by water is and what the cost of transportation by rail is, including all these factors, because when the American people have to pay the bills they are entitled to know where the money goes. Then if it is shown that the cost by water transportation is still somewhat greater than it is by rail, bring in these other advantages and view it as a comprehensive project of reclamation as well as transportation. If you can prove it out on that basis, then I say go ahead and I would favor the plan, but until such an investigation is made I shall be very skeptical, and I shall expect to see an expenditure within the next ten years of hundreds of mil-

lions of dollars which we, the American people, will pay in taxes in the development of projects which will not give us anything like a return upon our investment.

Mr. Brent: In a large measure I agree with what Professor Moulton has said. There are many water projects which are not proper projects. We have before us here now for consideration just one project which is of interest to the city of Chicago. That is the Illinois Waterway project. The Illinois Waterway, as a connection of the Mississippi and as a through route to the Gulf, is the thing which should, and I think does, interest the people of Chicago. Professor Moulton takes the assumption from the German experience that agricultural products cannot and will not prove successful by water. That is not the experience of the United States and Canada. We all know that the bulk of our grain which goes outward from Chicago and the head of the Lakes moves by water, and requires, unfortunately, trans-shipment in cars, and yet moves much more cheaply. Whatever has been expended upon the lakes, upon that waterway—and my recollection is that they have expended upon the locks at the Soo alone between sixty and eighty millions—has been a direct return to the people of the United States. The price of grain is fixed in Liverpool and every cent of saving reflects right back to the farmer through the grain channels.

There is one phase of the situation with which I am probably a little more familiar than is Professor Moulton, and that is the internal structure of our freight rates. We have in this country a series of concentrating points. All of our products grown to the westward are concentrated at Chicago. It is not proper or probable that the grain which is grown on the millions of fields in this country will be drawn directly to the water, but it is true that a very vast portion of the grain grown in the United States —I think last year something like 750,000,000 bushels—was concentrated at Chicago. When it gets here it is subject to either rail or water transportation to the Gulf or to the Atlantic, because so much of it must be exported. It is to the interest of Chicago to see that her outlets both to the South and to the East are the cheapest possible outlets. Now the expenditure of that twenty millions of dollars upon the Illinois Waterway can be, and probably will be, as directly reflected in transportation savings as has been the saving of the cutting out of the Lime Kiln Crossing at Detroit, and the deepening of the St. Mary's River, and the building of the second and third, and now the fourth canal at the Soo. These things have been directly reflected. They are hauling grain today from Duluth to Buffalo at three cents a bushel. The best rail rate you have from Chicago to New York is 21 cents a hundred pounds, and that will probably go up twenty or twenty-five per cent again before you get through with it. We have no coal which will probably use the Illinois Waterway or the Mississippi River to any great extent, but we have only to look at the comparative cost of getting coal into the Northwest as evidence of

the relative cheapness. The rate on coal from the interior of Illinois to Duluth is about four dollars a ton, while coal is being hauled from the Lake Erie ports to Duluth at sixty cents a ton, and before the war the average cost from Ohio points to Duluth was thirty cents a ton, while the railroads say they cannot handle it at four dollars a ton and make any money. The rate from the Messabe Range to Duluth is eighty cents a ton, and there is not probably in railroading an operation which is carried on in so economical a manner. It is carried in train loads; it is loaded automatically and unloaded automatically. It is carried down to Duluth and the cost is eighty cents a ton. Then they can carry it to Ohio points at sixty cents a ton, where it is loaded on the railroads and carried about one hundred to one hundred and twenty-five miles from the lake ports to Pittsburgh at the present time for about one dollar a ton; one hundred twenty-five miles for eighty cents, eight hundred sixty miles for sixty cents; one hundred miles for one dollar; there you have your comparison. I don't know of any better evidence in this country than that.

As to the Mississippi River—I have no grief for the fourteen-foot channel. Professor Moulton's statement concerning the evidence of the army engineers had to do with the fourteen-foot channel. That is a channel that will never be maintained for any great length of time. We do not need a fourteen-foot channel, and the Illinois Waterway as now planned does not call for a fourteen-foot channel; it calls for fourteen feet over the miter sills of the locks, a depth of eight feet through the dirt and nine feet through the rock cuts. Given a nine-foot channel from Chicago to the Gulf we can carry ten thousand tons of freight at one tow and that is as much as is necessary to operate cheaply on any waterway under present conditions. There is no particular merit on bringing ocean watercraft to Chicago. The cost of that would be prohibitive. There is no particular good in taking lake craft to the Gulf of Mexico on a fourteen-foot channel, because they cannot operate economically on the sea. There is one great difficulty with internal and ocean carriage. What you want on an internal operation is a wide shallow craft; what you need for the ocean is a narrow deep craft. The two do not go together at all. But trans-shipment is not the worst of our problems. That is necessary on all of the commerce that goes to New York. Everything that goes to New York today by rail must be trans-shipped. Everything that goes to New York by water today requires to be trans-shipped twice. But I do believe that these economies are present in a nine-foot channel from Chicago to the Gulf, and twenty millions spent for that will be returned not only in direct savings to transportation but to the people of the whole West that use Chicago as a market.

Question: May I ask whether there is any toll charged through the St. Mary's River and the locks?

Mr. Brent: None whatever; further than that the boats of either nation can use the canals of either nation.

Question: The Welland canal boats, so-called, running between Chicago and Montreal carry two thousand tons. Why could they not be economically operated on a fourteen-foot draft? Many steamers crossing the ocean carry three thousand tons gross. In fact the Shipping Board built two or three million tons of that same character of ships. On a fourteen-foot draft through the Illinois and Mississippi rivers why would it not be economical to carry grain to the Gulf with these steamers? What would be to hinder the loading of a three-thousand-ton boat with two thousand tons to New Orleans, taking on another thousand tons and going through the Panama Canal and on to the ports of South America? As far as safety is concerned, the average boat up to twenty-five or thirty years ago on the Atlantic Ocean didn't take much more than three thousand to thirty-five hundred tons dead weight. Why would it not be economical to build that type of boat and run those from Chicago straight through to South America, make Chicago a seaport by the Gulf as well as by the Atlantic. It is a seaport now by the Atlantic. There was no novelty about sending steamers out from Chicago to Hamburg and London back in 1900 when the canals were just opened. They carried then sixteen or seventeen hundred tons of cargo because the St. Lawrence canals had not been developed to their present state of efficiency. The question, it seems to me, is as to what would be the economical draft of water on which a steamer could operate from Chicago to the Gulf, and why would it not be feasible to operate as from Chicago to Montreal? It all depends upon the character of the cargo that you put on them. On the shallow boat you can carry a greater excess of dead weight cargo than you can on the narrow built boat, and you don't want a sharp built boat on ocean transportation, because she will be fitted for dead weight cargo but not for economical carrying. We built two of those on the Great Lakes twenty years ago and they were a financial failure; we had to load them with pig iron to get them down to their "marks," as it is called. I ask why a fourteen-foot channel is not economical, and if it is feasible, why not go ahead on those lines which really would make Chicago a seaport? It is no different than handling freight from here to London or Hamburg or any other place. The same steamers that we are building on the lakes, carrying three thousand tons, are loaded at New York and run to London. I would like to have an explanation made as to why it is not a feasible proposition.

Mr. Brent: There is only one answer and that is that a three thousand or a four thousand ton boat will not pay in ocean carrying against a fifteen-thousand-ton boat. The Shipping Board built two hundred of these ships on the Great Lakes. They built them wholly because they couldn't get a bigger ship out through the Welland Canal, and they did not go on with the program a moment

after the contracts were completed. As for their present building program, they have canceled every contract that calls for a ship of less than eight to ten thousand tons capacity. The whole fact is that you cannot compete with the larger boat on the ocean.

Heavy Coast Artillery

By D. A. Tomlinson, A. W. S. E.

Of all the different branches of the army, the coast artillery is one of the most technical, and requires a high degree of engineering skill, and yet it is possibly the least known among engineers. This is mainly because our coast defenses are located at the entrances to harbors and navigable rivers, often on islands or sand pits, and are thus more or less isolated, not only from engineers and the public generally, but also to some extent from the other branches of the army as well. However, at these coast defenses there are engineering problems of no small magnitude even in peace times. The construction of battery emplacements, the installation of guns and equipment, the location and survey of position finding systems, are all purely engineering work, requiring the services of experts. Furthermore, the actual firing of the guns, from the study of "Ballistics" to cleaning the bore, is really an engineering problem.

During the war the coast artillery corps of our army not only manned our coast defenses, as its name implies, but also furnished the heavy artillery regiments for service in France. Thus, "Coast Artillery" and "Heavy Artillery" are merely two names for the same branch of our army. In field service with heavy artillery, engineers are even more necessary than in garrison service at the coast defenses. At a coast defense the purely engineering work is done once for all, but in the field it has to be done anew every time the battery moves, and sometimes oftener. A large amount of precise surveying is necessary before heavy guns can be fired accurately; large scale, detailed, accurate maps must be prepared and studied; the battery must be emplaced and camouflaged; and finally the firing data must be carefully computed before each firing, which requires a high degree of technical skill. Thus a heavy artillery officer must really be an engineer, although he does not have that title. On the staff of every heavy artillery battalion, regiment and brigade were one or more orientation officers, who supervised the engineering work of their organizations. They were usually men who have had practical engineering experience before the war, and who have successfully completed a rigorous special course of training after receiving their commissions. Furthermore, all battery officers are required to be able to do this work. The articles on "Maps and Quadrillage for the Heavy Artillery" and on "French Surveying Methods" in a recent issue of *Engineering News-Record* bring out some of the engineering work of the heavy (coast) artillery, and show the great importance of engineers in that branch of the service. During the war a large number of engineers entered the coast artillery corps, and at the coast artillery training camp at Fort Monroe, and later in the field, they uniformly made splendid records.

The United States Coast and Geodetic Survey, and the United States Geological Survey have adopted a Lambert projection and system of co-ordinates for certain future maps of the United States, some maps of military reservations having already been completed on that system. The use of that projection and system of co-ordinates will probably grow, and engineers should become familiar with it, and with the surveying methods adapted for use therewith that have been developed by the French heavy artillery.

Maps and Quadrillage for Heavy Artillery

Prior to this war, heavy artillery was used only in warships and permanent fortifications, the latter being mainly coast defenses. Two types of artillery developed—field artillery and coast artillery—with widely different qualities, purposes and methods. In the former, mobility and rapidity of fire were the prime requisites; in the latter, power and accuracy. Field artillery, typified by the French 75, was small, light, easily operated and moved, but of limited range and power. Coast artillery, typified by the 15-inch naval guns, as large, heavy, permanently emplaced and machine operated, but had great range and power.

The two types had distinctive methods of fire. Field artillery, accompanying a mobile army in open warfare, found the approximate range and direction of the target, and in case of indirect fire, of an aiming point also, by a rapid reconnaissance or by estimation, opening fire within a few minutes if necessary. Then by observing the bursts of his shrapnel, a battery commander would gradually get his shots on the target. Heavy artillery, on the other hand, intended for the defense of a definite point, such as a harbor or city, was permanently mounted in concrete emplacements. Its zone of fire was carefully surveyed and mapped so that the exact range and direction of all points was known. All variables that might affect the flight of the projectile were considered and suitable corrections made; for instance, wind, temperature and pressure of the air and the temperature and condition of the powder. These operations involve a large amount of preparation before firing and considerable equipment, but secure a high degree of accuracy. They are essential for large calibre guns, but are relatively unimportant for smaller guns, and were largely omitted by field artillery in order to simplify the work and save time and weight. Few people thought that seacoast guns and methods would be used in field warfare, particularly to the extent that is the case today.

When the Germans intrenched themselves in the "Hindenburg Line" after the battle of the Marne, the war on the western front became a siege between two strongly intrenched opposing armies, each supported by its artillery. On each side the trenches often ran back thousands of yards and presented an almost impregnable front. For either side to advance its artillery must first batter a way

through the opposing defenses. To secure artillery of the range and power necessary to do this, and to match the German heavy guns, the allies mounted heavy seacoast and naval guns on mobile carriages, using special railroad cars for the larger ones. At first, it was attempted to fire these by field artillery methods but that system was not suitable for heavy guns or siege conditions. Ammunition was being wasted, guns and personnel were being lost, and worst of all, the fire was not effective. Therefore coast artillery methods, modified to suit land warfare, were gradually adopted.

These require first of all the accurate determination of the range and direction of the target, i. e., the length and direction of an imaginary line from the gun to the target; the elevations of the gun and target, and the location, with respect to the gun and target, of one or more observing stations from which the fall of the shots can be seen. This work constitutes the "topographic preparation for fire" which is the foundation of heavy artillery work. To make these topographic preparations efficient, the artillery requires accurate, large scale maps, from which, incidentally, a large amount of other valuable information can be obtained. Therefore a large part of the western front has been re-mapped since the war began, on the Lambert projection, using a system of rectangular co-ordinates. This projection, although devised over a century ago, has been but little used until recently. It is of particular value for artillery work, because it preserves angles, which are of prime importance to the artillery. The system of rectagular coördinates is based on the projection, and is really only the extension of the American method of latitudes and departure over a large area. The system of projection and coördinates are taken up in this article, and in another, certain methods of surveying that have been developed by the French Heavy Artillery for use therewith.

Map Projections.—As the earth is spherical, while a map is necessarily a plane surface, it is impossible to represent any large portion of the earth's surface on a map without some distortion, either in angles,, distances or areas, or all three. For most civil maps, simplicity and the preservation of areas are the most important qualities. But for military maps, to be used by the heavy artillery, the essential quality is the preservation of angles. Because of several unavoidable causes, all guns have a certain amount of "dispersion," i. e., no two shots fall in the same place. A large group of shots fired under the same conditions form a rectangle, whose length (in the direction of fire) is about seven times its width. Thus slight errors in the range have but little effect, merely moving the center of impact of the group of shots slightly from the target, but a slight error in direction may throw a group of shots entirely off the target, particularly if the range is great. Therefore, directions and angles must be accurately known.

There are several projections that preserve angles, viz., Lambert's, Mercator's, and the Sterographic, which are closely related,

as will be shown later. Lambert's is well adapted for an area in medium latitudes, and extending mainly in an east and west direction. Therefore, it was the one chosen for the new French battle maps.

In any system of projection it is sufficient to plot the parallels of latitude and meridians of longitude over the area involved until a network is constructed outlining sub-areas small enough to be considered as planes. With such a framework established intervening topographic detail may be drawn as flat surfaces. Therefore only parallels and meridians will be considered in describing Lambert's projection. The English system of latitude and longitude is too well known to require any description here, but in their new battle maps the French used their own system of latitude and longitude, which is based on the metric system of angular measurement. The circumference of a circle is divided into 400 grades, each grade into 100 centesimal minutes, and each centesimal minute in 100 centesimal seconds, a decimal system being thus attained: $60^g—15'—12''$ (60 grades, 15 minutes and 12 seconds) is the same as 60.1512^g. Compared with our system of angular measurement, $100^g = 90^\circ$. This system of angular measurement is applied to latitude and longitude as follows: The initial meridian (0^g) is the meridian of the Paris observatory ($2^\circ—14'—20''$ E) and longitude is measured from 0^g to 200^g in both directions, west longitudes being called plus and east longitudes minus. Latitude is measured from 0^g at the equator to $+100^g$ at the north pole and -100^g at the south pole. Latitude as commonly used in America means true latitude, i. e., the angle which a line to the center of the earth makes with the plane of the equator. The French use geodetic latitude, i. e., the angle which a normal to the earth's surface makes with the plane of the equator. At the equator and the poles geodetic latitude is the same as true latitude; at all other points it is greater, the maximum difference being $11'—30''$ at 45° latitude. One kilometer nearly equals one centesimal minute of latitude.

Theory of Prejection.—To preserve angles any area on the map must be similar to the corresponding area on the ground. This can be exactly attained only for infinitely small areas, but the curvature of the earth is so slight that in Lambert's projection as used in France it is practically attained for areas up to 100 kilometers square. To secure exact similarity the distortion would have to be the same at all points. This can be attained only on a globe, but the distortion at any one point on a map can be the same in all directions, although it may vary from one point to another. When this condition exists the map is said to be conformal: Lambert's porjection is conformal. Further, the distortion is the same at all points on any one parallel, varying only along the meridians, where, as will be shown later, the variation is slight in the belt of latitude involved.

Every projection has an origin, which is usually taken at some

point near the center of the area to be mapped; its parallel and meridian become the initial parallel and initial meridian of the projection. For the new French maps the origin was taken at a point near Treves, Germany, whose latitude is $+ 55^g$ and longitude is $- 6^g$. This is about the center north and south of the "Hindenburg Line" and is about midway from there to central Germany. A cone is imagined to be placed over the earth, tangent at this parallel, and therefore having its vertex in the earth's axis produced. The planes of the meridians are extended until they cut this cone, intersecting it in straight lines. When the cone is developed, i. e., unrolled, the meridians appear as straight lines radiating from its vertex, and the initial parallel as an arc of a circle having the vertex as a center.

From the condition that at any point the distortion must be the same in all directions a formula is mathematically derived for the spacing of the parallels. It is $P = K\ (\tan \frac{Z}{2})^h$. (Note: This formula applies to a sphere. When the earth's spheroidal form is considered, another factor is added to this formula which need not be considered here.)

Where P is the radius of any parallel, Z its co-latitude (90° lat.), K an arbitrary constant and h the sine of the initial latitude. Depending on the value given K, the formula represents the results that would be attained from a series of parallel cones. If the value is unity the formula represents the original cone, i. e., the cone tangent at the initial parallel, and distances will be correct along the the initial parallel. If the value be less than unity, the formula represents a cone parallel to the original cone but cutting the earth instead of tangent to it. In other words, imagine the original cone to be pushed down, parallel to itself, until it cuts the earth at any two parallels that may be selected. It is still at right angles to the normal to the earth's surface at the initial parallel, but distances are now correct along those two parallels instead of along the initial parallel. Between those two parallel points are being projected down onto the cone, distances thereby being decreased, and beyond them points are projected out onto the cone, those distances thereby being increased.

If the value of K is so selected that one of the two standard parallels is 1/6 of the map's range in latitude below its northern limit, and the other 1/6 above the southern limit, the linear distortion at the center of the map will equal that at the edges, although it will be in the opposite direction, distances at the center being less than the corresponding distances on the earth, and distances at the edges greater, the total linear distortion being minimized. It was desired to have the new battle maps extend in latitude from $+ 52^g$ to $+ 58^g$, the former passing through central Switzerland and the latter through northern Holland. Therefore the cone adopted cuts the earth at parallels $+ 53^g$ and $+ 57^g$, on which distances are preserved. To do this the factor K in the general

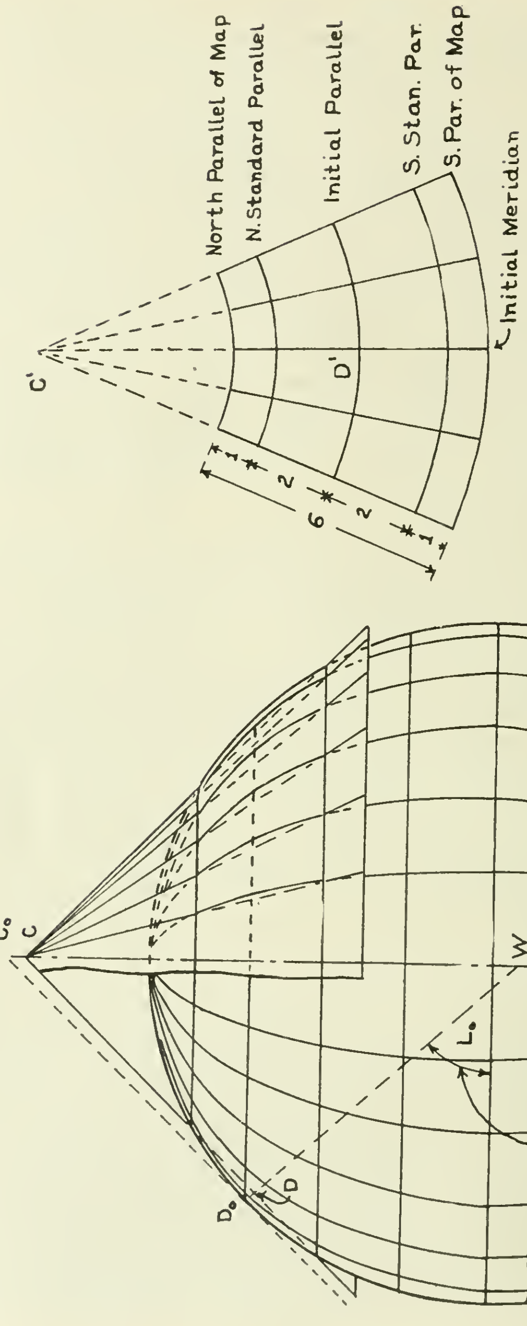

Fig. 1. Lambert's Projection

formula is given a value of 2036/2037, which amounts to diminishing all basic distances used in making the map by 1/2037.

Relation to Other Projections.—The angle between meridians on the map depends on the slope of the cone, or in other words on the initial parallel. The ratio of the angle between meridians on the map and their difference in longitude is the sine of the initial latitude. This is the exponent "h" in the general formula. It can vary from zero to unity. At one limit ($h = 0$) the cone becomes a cylinder tangent at the equator, and meridians and parallels are straight lines at right angles to each other. This is Mercator's projection, which is much used for ocean charts and maps of the world. At the other limit ($h = 1$) the cone becomes a plane tangent at the pole, meridians intersecting at angles equal to their differences in longitude, and parallels becoming complete concentric circles. This is one type of zenithol projection, and is similar to the stereographic, both of which are used for maps of the polar regions. At either extreme, as well as in the general case, the projection is conformal.

Construction of the Maps.—The slant height of a cone tangent to the earth at the initial parallel is computed from that latitude and the length of the normal to the earth's surface at that point. (See Fig. 1.) Calling this slant height CoDo, the initial latitude Lo, and the length of the normal, DoW, we have the formula CoDo = DoWCotg. Lo. This slant height CoDo, diminished by 1/2037 as explained above, gives the slant height, C D, of a second cone, parallel to the first, but cutting the earth at the two standard parallels. A straight line C'D', equal to C D is laid off on the map to represent the initial meridian, and with C' as a center and C'D' as a radius an arc is drawn representing the initial parallel. Along this arc distances between meridians on the earth's surface at that parallel, diminished by 1/2037, are laid off, and through the points thus established radii are drawn representing the meridians.

The radius of each parallel could be computed from the general formula ($P = K (\tan \frac{Z}{2})^h$) but that is awkward to use. It can be converted into a formula that gives the spacing of the parallels from the initial parallel and is easier to use. The new formula appears as a series of terms, each smaller than the preceding, the precision of the result depending on the number of terms considered. For the range in latitude to be covered by these maps only two terms need be considered and the formula used is $B' = B + \frac{B^3}{6R^2}$ where B is the meridian distance on the earth from the initial parallel to any other parallel, B' the corresponding distance on the map and R the mean radius of the earth at the initial parallel. The distance to any parallel, computed from this formula and diminished by 1/2037, is laid out along the initial meridian and through the point thus located an arc is drawn to represent that parallel.

Results.—Any straight line connecting two points on the earth's surface is actually a "great circle," i. e., it is the intersection of a plane through those two points and the center of the earth with the earth's surface. Any horizontal angle is the angle between two such great circles. To preserve angles, therefore, all such great circles should appear on the map as straight lines, but because the distortion varies in a Lambert projection, great circles appear as slight curves. However, the curve is so slight that for distances up to 100 kilometers it is imperceptible and can be regarded as a straight line, the angular error being less than a minute. Therefore for all practical purposes angles are preserved.

On the two standard parallels, $+ 53^g$ and $+ 57^g$, distances are correct; between them distances are decreased, and beyond them they are increased slightly, the maximum linear distortion being only 1 in 2037, or less than 0.05 per cent. Thus for a belt 6 grades of latitude (600 kilometers) in width, the linear distortion is negligible; angular errors are inappreciable, and areas are nearly correct. Any single large scale map of a portion of this area made on this projection is really just that portion of a small scale map of the whole area magnified to a larger scale. Adjacent maps can be used together without introducing any errors, because they are merely parts of one general system of projection. In brief all the requirements for accuracy in artillery fire are met and excellent maps are produced.

Rectangular Coördinates.—But heavy artillery requires more than accurate maps in long-range land warfare. To execute map firing successfully a battery commander must know the exact positions on the map of his guns and targets, and often of other points as well. To determine a position by reference to local detail is not accurate, particularly on a small scale map. Moreover, local detail—buildings, trees, roads, etc.—in the war zone often changes over night. Therefore a system of rectangular coördinates are superimposed over the entire battlefront, its origin being the origin of the projections. This is similar to the system of "Latitudes and Departures" often used for plotting surveys in the United States, but is extended over an area of thousands of square miles. The initial meridian ($—6^g$) is taken as the Y-axis, and a line perpendicular thereto at the origin as the X-axis. Lines parallel to these two axes and one kilometer (1,000 meters) apart are ruled on the maps, forming what is called the "Kilometric Grid." To avoid the use of negative coördinates the origin is given arbitrary coördinates of large size, viz., $X = 500{,}000$ and $Y = 300{,}000$ meters. The coördinates are expressed in several ways—in kilometers, in hectometers (1 hectometer = 100 meters) or in meters. The coordinates of any point can be scaled from the map, or vice versa, any point can be plotted on the map from its coördinates, the latter being of great value in making the maps as well as in using them.

The coördinates of a point determine its location, and from the coördinates of two points the length and direction of the line

joining them can easily be found by solving a right triangle. In using coördinates only a knowledge of plane trigonometry and logarithms is necessary, which is in itself an advantage. To various triangulation points, traverse stations and benchmarks used in the surveys for these maps are all listed with their coördinates, and these lists are available to officers needing them. From these known points and the map the coördinates of any point desired, such as a gun position, can be found from the map or by surveys.

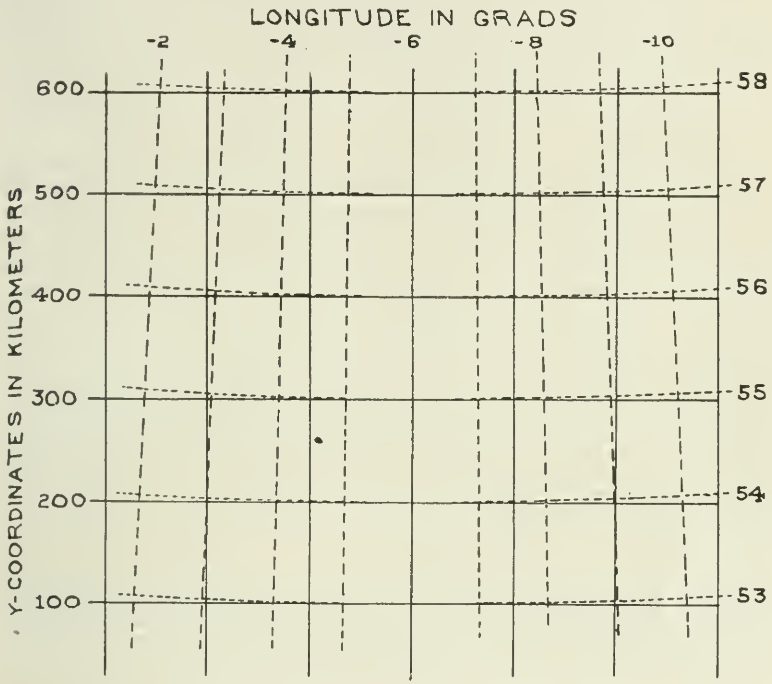

Fig. 2. Lambert's Projection, Kilometric Grid

The direction of the meridian at any point defines true north. "Grid North" at any point is the direction of a line parallel to the Y-axis (initial meridian). Away from the origin grid north diverges from true north, because the meridians converge at a point—the apex of the cone. East of the origin grid north is east of true north and west of the origin is west of true north, the amount of the divergence depending on the distance from the initial meridian. At any point the divergence of grid north from true north is the same as the angle between that meridian and the initial meridian (i. e., the convergence of meridians) and is equal to the difference in longitude times the sine of the initial latitude. Calling the convergence oC; the initial meridian (-6^g), Mo; the initial lati-

tude (+ 55^g), L_0; and the meridian of any point M, the convergence can be expressed in a formula as follows:

$$oC = (M - M_0) \times \sin L_0 \text{ or}$$
$$= (M + 6^g) \times .76$$

In case true north is found by astronomical observation, as is frequently the case in artillery work, grid north can be found by applying the convergence as found by this formula to true north in the proper direction. The Y-azimuth of any line is the angle from grid north to that line, measured clockwise. As stated before, angles are of prime importance to the artillery and it is necessary to know grid north accurately at all times.

As a system of rectangular coördinates can only be applied to a plane surface, these coördinates are based on the projection, i. e., on the basic cone when unrolled. Therefore, fitting the projection, they contain its linear distortions, and away from the two standard parallels the distance between two points as determined from their coördinates is the map distance between them and is not quite the same as the actual distance on the ground. However, the angle between any two lines as found from coördinates is correct. In order to minimize the effect of this small linear error, and to utilize the accuracy of angles, more reliance is placed on the latter than is usually the case in American surveying. In this connection the French have devised certain methods of intersection and resection which depend on coördinates, the accurate measurement of angles and an accurate orientation of the transit at each set up. These methods give the coördinates of the point sought directly, distances not being measured at all. They will be described in the following article.

The data for this article was obtained from the following sources, to which acknowledgment is hereby made: Encyclopedia Britannica, Special Publication No. 47, U. S. Coast and Geodetic Survey, and various bulletins of the American Artillery School in France. The article was prepared at the Coast Artillery Training Camp, Fort Monroe, Va., and has been approved by Col. R. R. Welshimer, Commandant, Lt.-Col. R. E. Guthrie, director of instruction, and Major E. A. Ziegler, senior instructor in orientation.

French Methods of Intersection and Resection

Lambert's projection and the kilometric grid, used for the new French battle maps, were described in the first article. This kilometric grid, or system of rectangular co-ordinates as it is sometimes known, is based on the projection, and contains the same linear distortions, while angles are preserved. Consequently, if the distance between two points is computed from their co-ordinates, and is also measured on the ground, the two values will not agree unless the line is at or near one of the two standard parallels. This discrepancy is the linear distortion in the projection, and is small—always less than 0.05 per cent on the maps of France—but it must be considered in surveys and computations which are based on the grid system, otherwise a serious accumulative error may be introduced. Consequently the use of linear

measurements is minimized and surveying work is largely confined to problems in intersection and resection in which only co-ordinates and accurately measured angles are necessary. Resection was particularly valuable in locating gun positions and observation posts, and intersection in locating targets behind the enemy's lines.

In using these two methods and co-ordinates there are certain sources of possible error, whose effect should be minimized. There may be slight errors in the given co-ordinates of the known points on which the survey is based, and there may be slight errors in the transit field work. For instance, if the co-ordinates of the ends of a base line 1,000 meters long, which is to be used in intersection, but which cannot be measured directly, are reliable only to the nearest meter, there is a possible error of one meter in its length and of 3 minutes in its direction. If the co-ordinates of an enemy position 10 kilometers away are to be found from this base line a considerable error might creep in. Furthermore, the information desired from surveys on the western front is the co-ordinates of certain points, rather than their distance and direction from any particular known points. Having found the co-ordinates of his gun position, say by resection, a battery commander is in a position to calculate the range and direction to any target whose co-ordinates may be given him. Vice versa, two observation posts, whose co-ordinates are known, can often take angular readings on the same flash of an enemy gun, from which its co-ordinates can be computed. It can then be assigned as a target to any battery desired.

The French method of intersection, and their method of resection—called "Relevement," which translated means resection, are based on the accurate measurement of angles in the field, and the accurate determination of the direction of the various lines of sight, direction usually being expressed as the angle from grid north clockwise to the line in question, i. e., its "y-azimuth." From this data the co-ordinates of the unknown point are found directly by a graphical solution, supplemented by computations, without recourse to linear measurements at all. Intersection and resection are very similar, the latter being merely the reverse of the former. Intersection will be presented first.

FRENCH METHOD OF INTERSECTION.

In order to minimize the effect of errors, three or more known points are generally used as transit stations, although the method is equally applicable to a pair of points. The transit is set up at each of the known points in turn, and the y-azimuth of the line of sight to the unknown point is found either by means of an astronomical observation, or by making the "round of the horizon," as it is called. In the latter case the angles between the unknown point and several known points are measured; from the co-ordinates of the transit point and each of the known points in turn, the y-azimuths of the latter are computed; from each of these

y-azimuths and the corresponding measured angle to the unknown point, an independent value of the y-azimuth of the unknown point is found. Because of slight errors in the co-ordinates, or in the

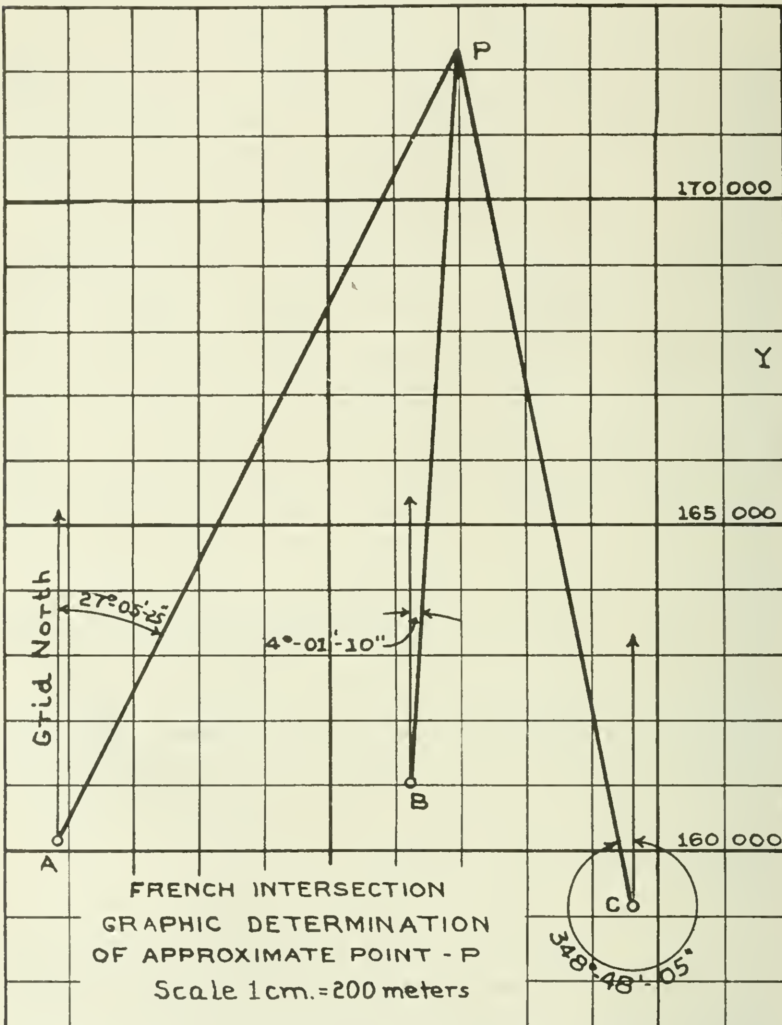

Fig. 1. French Intersection. Graphic Determination of Approximate Point—P.

measured angles, these independent values may vary slightly. Their mean value has a very small probable error, however, and is adopted as the true value. The method is discussed more fully under resection.

The known points are plotted on cross section paper to a convenient scale—say 1 cm. = 200 meters. (See Fig. 1.) The line of sight (ray) from each known point to the unknown point is then plotted by means of its y-azimuth, found as explained above. The intersection of the different rays locates the unknown point, and its co-ordinates are read directly from the diagram. If a large enough scale were used, these could be read to within one meter and nothing more would be necessary. But to keep the diagram down to a convenient working size, the scale must be small, and the co-ordinates of the unknown point can only be read approximately, say to the nearest 10 meters, depending on the scale used.

These approximate scaled co-ordinates represent an actual point on the ground, called the "approximate point." From these scaled co-ordinates, and those of the known points, the y-azimuths of the rays from the known points to the approxiate point are computed. This gives the y-azimuth of two rays from each known point, viz., the true rays to the true point, whose y-azimuth was measured in the field, and the approximate ray to the approximate point, whose y-azimuth was computed as above. The angle between the true ray and the approximate ray at each known point, called "d0," is equal to the difference in their y-azimuths. (See Fig. 2.) If the true y-azimuth is greater, the true ray lies to the right of the approximate ray, and vice versa. If the vicinity of the approximate point is plotted to a large scale, showing the true rays, their intersection willl be the true point. The approximate rays can be plotted from their y-azimuths, but the location of the true rays with respect to them must be computed. As explained above, an inspection of the two Y-azimuths shows whether the true ray is to the right or left of the approximate ray. The only other data necessary for plotting the true ray is its distance from the approximate ray. That distance (Q) is evidently equal to the length (D) of the approximate ray times the sine of d0, or Q = D sin d0.

That computation can be made by slide rule readily if d0 is converted from minutes and seconds to mils, a unit of angular measurement much used by the artillery. There are 6,400 mils in a circle; $360° = 6{,}400$ mils; or 1 mil = 202.5 seconds, which is a convenient relation to use in converting d0 to mils. The great advantage of the mil system is the fact that the natural tangent of one mil is 1/1000. Thus at a distance of 2,000 meters, 1 mil subtends a distance of 2 meters, 1.5 mils subtends 3 meters, etc. Then if d0 is expressed in mils, $Q = D \times \frac{1}{1000} \times d0$, which can be worked out mentally or by slide rule. The lengths, D, can be scaled from the small scale diagram, Fig. 1, with sufficient accuracy.

Using this data a large scale (say 1 cm. = 1 meter) diagram of the vicinity of the approximate point is drawn. (See Fig. 3.) The approximate rays, converging at the approximate point, are plotted from their y-azimuths. Then the offsets (Q) are laid out in the proper directions, and through the points thus located the

true rays are plotted, being drawn parallel to the approximate rays, because in the short distance involved their divergence is appreciable. Instead of intersecting at a point the true rays usually form a small figure of error, called a chapeau, whose center is taken as the true point. Its co-ordinates are then scaled directly from the diagram, and the problem is solved.

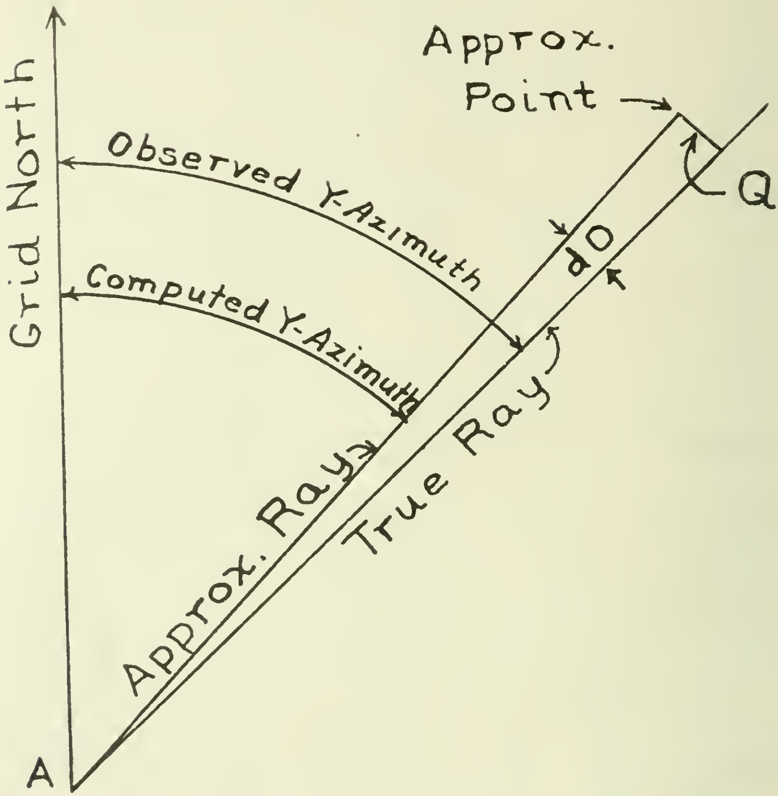

Fig. 2. Scale Diagram

The following example illustrates this method. The co-ordinates of the known points, and the y-azimuths of their respective lines of sight, to the unknown point, as determined in the field, are as follows:

Point	X Co-ordinate	— Y	Y-azimuth of line of sight to unknown point
A	135,818	160,245	27°—05′—25″
B	141,220	161,024	4°—01′—10″
C	144,633	159,154	348°—48′—05″

From a small scale diagram (see Fig. 1) the co-ordinates of the approximate point (P) are found to be X = 142,020 and Y =

172,360. The computations of the data necessary for a large scale diagram, arranged in convenient tabular form, are as follows:

Item / Line	AP	BP	CP
	142,020	142,020	142,020
$\triangle X$	135,818	141,220	144,633
	6,202	800	2,613
	172,360	172,360	172,360
	160,245	161,024	159,154
$\triangle Y$	12,115	11,336	13,206
Log $\triangle X$	3.792,532	2.903,090	3.417,139
Log $\triangle Y$	4.083,323	4.054,460	4.120,771
Log tan bearing	9.709,209	8.848,630	9.296,368
Bearing of Approx. Ray......	N 27°—06′—33″ E	N 4°—02′—12″ E	N 11°—11′—32″ W
Approximate y-azimuth	27°—06′—33″	4°—02′—12″	348°—48′—28″
Observed y-azimuth	27°—05′—25″	4°—01′—10″	348°—48′—05″
Difference —dθ*	— 1′—08″	— 1′—02″	— 23″
dθ in Mils....................	— 0.346	— 0.306	— 0.114
Scaled Length D	13,360	11,370	13,450
Offset to true Ray —Q........			
$Q = \frac{D}{1000} \times d\theta$	—4.71	—3.48	—1.53

Note: When the observed y-azimuth is less than the approximate y-azimuth the true ray lies to the left of the approximate ray. To indicate this, dθ and Q are then given minus signs.

A central point on a sheet of cross section paper is taken as the approximate point, the vertical and horizontal lines through it being given the proper x and y co-ordinates respectively. (See Fig. 3.) The other ruled lines are given co-ordinates according to the scale used. The approximate rays—or computed rays as they are sometimes called—are plotted from their y-azimuths, intersecting at the unknown point. From each such ray the corresponding value of Q is laid off at right angles thereto, to the right or left of the approximate ray as explained above. Through the points thus established the true rays are drawn parallel to their corresponding approximate rays.

If there were no errors of any sort, either in the co-ordinates of the known point, or in the y-azimuths measured in the field, these true rays would intersect at a common point. However, because of such errors in the initial data, they usually fail to do so, forming instead a small figure of error, or "chapeau" as the French call it. If the co-ordinates of the known points are assumed to be correct, then the error lies in the observed y-azimuths. Any given angular error therein will displace the true rays at the chapeau proportionately to their lengths. In that case the probable location of the true point is within the chapeau, and distant from each ray in proportion to its length. Vice versa, if the y-azimuths are assumed to be correct, the error that causes the chapeau lies in the co-ordinates of the known points. Any given error therein would displace all rays equally, each ray moving parallel to itself,

and the probable location of the true point would be inside the chapeau and equally distant from all the rays. The difference between these two locations is slight; usually less than a decimeter. Moreover the chapeau is probably caused by errors in both places. Therefore the center of gravity of the chapeau, which can be esti-

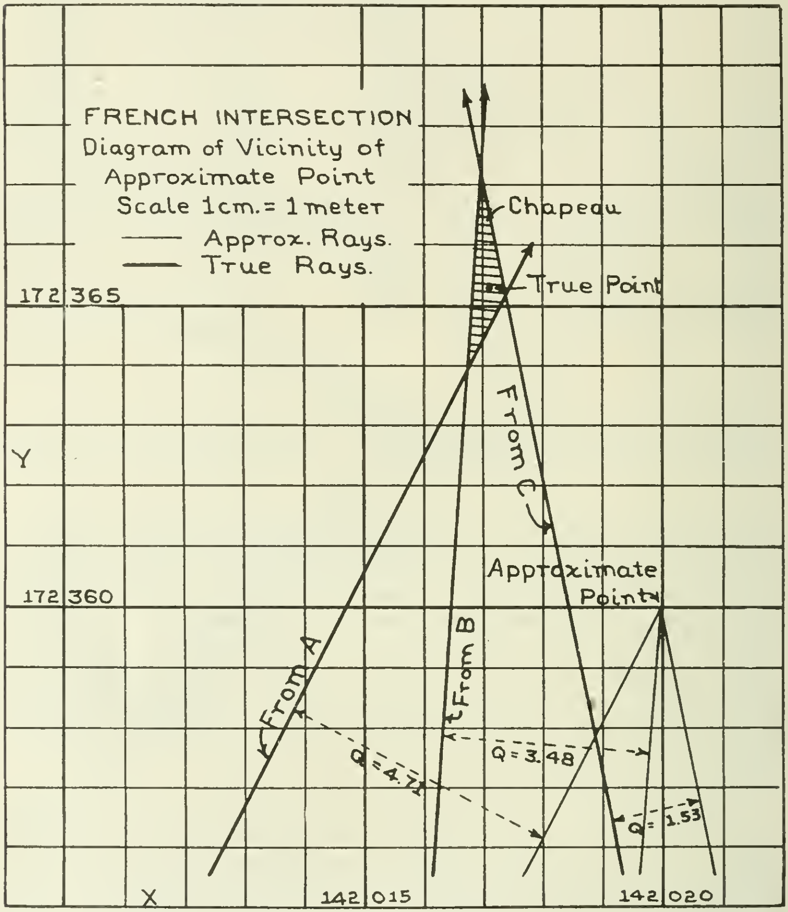

Fig. 3. French Intersection. Diagram of Vicinity of Approximate Point

mated by eye, can safely be adopted as the true point. The approximate point may be as much as 20 meters in error; the adopted point is probably correct to within less than a meter, which is sufficiently close for most purposes. If greater precision is required, the adopted point can be taken as the approximate point for a new set of computations and a new diagram on a still larger scale.

For the various reasons given at the beginning of this article, this method is well adapted for use with co-ordinates, especially

when linear measurements are not possible or desirable. It gives the co-ordinates of the unknown point directly, and with a small probable error, the effect of errors in the initial data being minimized. The computation of the field work, i. e., the computations of the observed y-azimuths, which has been omitted here, adds work that is not necessary in the usual methods of intersection, but the solution of the problem itself is simple. As in all methods of intersection, angles less than 30° should be avoided if possible.

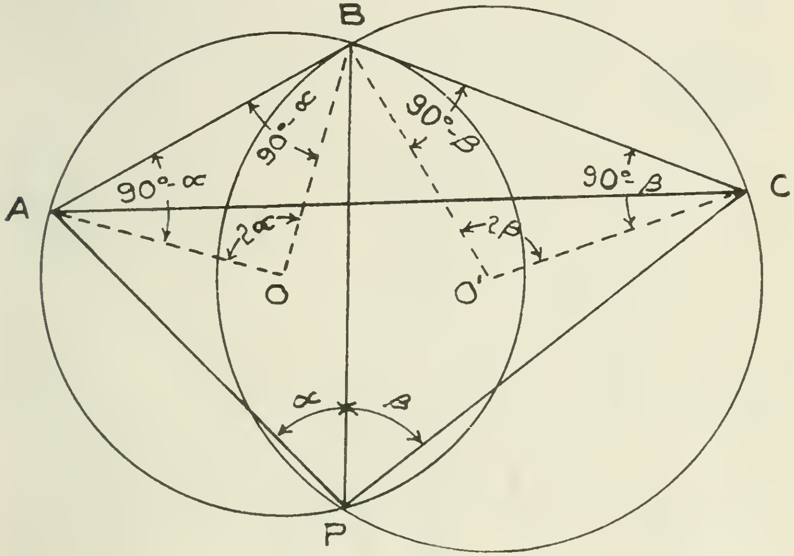

Fig. 4

RESECTION (RELEVEMENT)

In the United States resection is usually spoken of as the "three point problem," in which angles are measured at an unknown point between lines to three known points. From these angles and the known relations between the known points the position of the unknown point can be found in several ways. All methods of resection, including relevement, are based on the same geometric principles. In order to bring the points of similarity between relevement and the usual American methods, these principles and some of these methods will be briefly described in the following paragraphs. (See Fig. 4.)

An angle (oC) measured at any unknown point (P) between lines to two known points does not locate the unknown point (unless the instrument is oriented) but it determines a circle (A B P) passing through those three points (two known and one unknown). The central angle A O B subtended by the chord joining the two known joints is twice the angle A P B measured at the unknown point (an angle having its vertex in the circum-

ference of a circle is equal to half the angle subtended by the same chord and whose vertex is at the center of the circle). At any point on this arc A P B the angle oC will be the same. Therefore, the unknown point could lie anywhere on that arc. However, if a second angle (B) is measured at the unknown point (P) between lines to a third known point and one of the first two points, a

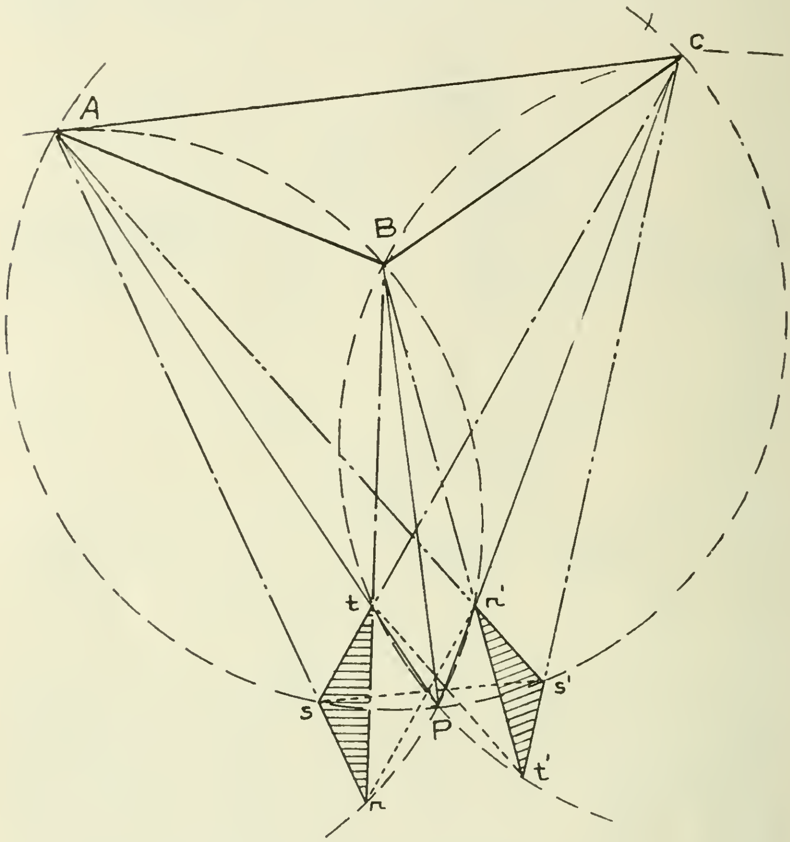

Fig. 5. Inverse Triangle of Error Solution

second circle (C B P) is similarly determined. As far as the second angle is concerned the unknown point could lie anywhere on the arc C P B. As it must lie on both arcs, it must be at their intersection, P. When the unknown point lies on the circle through the three known points, the two circles determined by the angles become coincident and the problem is indeterminate; if it lies close to that circle the solution is weak. Therefore care must be used to select suitable known points.

Graphical Solution: As stated above, the central angle A O B (Fig. 4) is twice the angle oC measured at the unknown point. Therefore in triangle A O B, A O and B O are radii, and $\angle$ O A B = $\angle$ O B A = 90° — oC. If the three known points are plotted to scale and angles equal to 90° oC are laid off at A and B, the intersection of the lines thus plotted locates the center, O, of the circle A B P. The center O′ of the second circle can be similarly found. With O and O′ as centers and O B and O′ B respectively as radii, the two circles can be drawn. The unknown point lies at their intersection, P. In relevement, an approximate point, similar to that used in intersection, is found in this manner.

Triangle of Error Solution: Each of the rays to the known points can be considered as pivoted at the proper known point. (See Fig. 5.) If the direction of one of them is known, or assumed, the direction of the others can be calculated, and they can all be plotted. If this orientation is correct, they have a common intersection (P) which is the unknown point. If this orientation is not correct, the three rays have three separate intersections, and form a "triangle of error" (r s t), the angles between them remaining the same. As the orientation is changed, each intersection or vertex, such as r, s or t, travels along the circumference of the circle determined by its angle. For slight changes in orientation the chord (called a segment by the French) connecting any two positions of each vertex can be considered as coincident with the arc. After the first triangle of error has been found, the position of the unknown point can be found in two ways, viz.:

First. By estimation, with the aid of certain well known rules, which can be summarized as follows: The unknown point is either to the right of all the rays, or to their left; it is distant from the rays in proportion to their length, viz., it is furthest from the longest ray; if the unknown point is inside the great triangle (A B C) formed by the known points, it is inside the triangle of error, and vice versa.

Second. By changing the orientation and drawing a second set of rays, forming a second triangle of error (r′ s′ t′, Fig. 5), preferably inverted, i. e., on the opposite side of the unknown point. As stated above, if the change in orientation is slight, lines connecting corresponding vertices of the two triangles of error can be considered as representing the arcs on which the vertices have moved, their intersection being the unknown point. The change in orientation should of course be much less than that indicated in Fig. 5, where a large change has been used for the sake of clearness. This is called the inverse triangle of error solution.

The application of both of these triangles of error solutions on the plane table is well known. In relevement, after the approximate point has been found by the graphical method an estimated orientation is computed that is closely correct, and the corresponding estimated rays are plotted on a large scale diagram of the vicinity of the approximate point, in the same manner as in intersec-

tion. If these form a triangle of error, or "chapeau" as the French call it, the orientation is changed enough to secure an inverted chapeau, which is then plotted. The segments connecting corresponding vertices of the two chapeaux are drawn, then intersection being taken as the true point. As compared with the plane

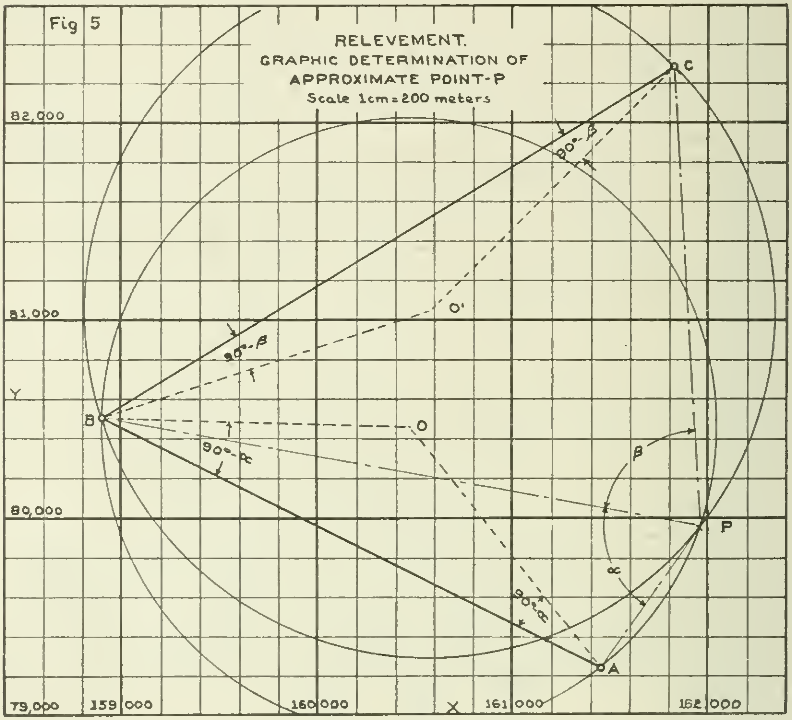

Fig. 6. Relevement. Graphic Determination of Approximate Point—P.

table solution, all relevement does is to magnify two small chapeaux and a small change in orientation, that would be invisible in small scale plane table work, to such a size that they can be used.

RELEVEMENT.

The field work consists of accurately measuring the angles at the unknown point between lines to three or more unknown points, usually by repetition. At least three known points and preferably four or five should be used, each additional point strengthening the solution. If possible the known points should be so selected that they are about equally distant from the observer, the angles between them nearly equal, and the points being on all sides of the observer.

If conditions permit, an astronomical observation can be made to determine the y-azimuth of one of the lines, in which case only two known points are essential. This gives the correct orientation, and the problem can then be treated as a problem in intersection and solved as explained in the first part of this article. However, the general case, i. e., when an astronomical observation cannot be made, is the more common, and will be considered here.

As in intersection, the first step is to find the approximate co-ordinates of the unknown point, i. e., the approximate point. This is done graphically by the graphical solution mentioned above. (See Fig. 6.) From these co-ordinates and those of the known points the y-azimuths—called "computed y-azimuths" of the approximate rays, i. e., the rays from the approximate point to the known point are computed.

The next step is to estimate the true orientation, or in other words, estimate the y-azimuths of the true rays from the unknown points. This is done by "making the round of the horizon," which was briefly mentioned under intersection. Any one of the known points, such as A in the example given below, is taken as the initial point, and the angles from it to each of the other points, measured clockwise, are computed from the observed angles, being called "transit readings." The transit reading of the initial point is zero, and that of any other point is the total angle to it, measured clockwise from the initial point. Deducting each transit reading from the corresponding computed y-azimuth, a series of independent values of the y-azimuth of the initial point are found, each based on the computed y-azimuth of one of the known points. If the approximate point coincides with the true point, these values will agree, otherwise there will be more or less variation in them, depending on the distance between the approximate point and the true point affects the computed y-azimuths of the approximate rays siderably in error because the computed y-azimuth on which it is based may be in error, but their mean value is closely correct, particularly if the known points lie on all sides of the observer, because the sum of the errors in the computed y-azimuths must then be zero. The distance from the approximate point to the true point effects the computed y-azimuths of the approximate rays inversely as their lengths, or in other words, the longer the approximate ray, the more reliable is its computed y-azimuth. Therefore, if the rays vary greatly in length a weighted mean should be used, each value of the initial y-azimuth being given a weight proportional to the length of the ray on which it is based. When the co-ordinates of the transit point are known, as in intersection, this method minimizes the effect of errors in co-ordinates and gives very accurate results. In relevement, when the co-ordinates of the approximate point may be considerably in error, it gives an estimated orientation that is closely correct. By adding the transit readings to this estimated initial y-azimuth, an estimated y-azimuth of each of the true rays is found.

As in intersection the next step is to construct a large scale diagram of the vicinity of the approximate point, showing these estimated rays. The difference, d0, of the computed and estimated y-azimuths of the rays to each known point, and the distance, Q, from each approximate ray to the corresponding estimated ray is found and the rays are plotted in the same manner as in intersection. If the estimated orientation is correct the estimated rays will have a common intersection, otherwise a "chapeau" will be formed. This chapeau is similar to the triangle of error formed on the plane table in the three point problem, and is due to the same cause, viz., an incorrect orientation. The only difference is that in relevement the vicinity of the true point is magnified on the large scale diagram, so that a chapeau that would be imperceptible on a small scale sketch becomes sufficiently enlarged to be used.

From this chapeau (see Fig. 7) the position of the true point can be estimated by the plane table rules mentioned above. However, the "inverse triangle of error" solution is better. To form a second and inverted chapeau it is necessary to inspect the first chapeau and determine whether the orientation should be increased or decreased to eliminate it. If it is decreased all the rays move to the left, as seen from the known points; if such a movement of the rays decreases the size of the chapeau, the orientation should be changed enough in the proper direction to form a second chapeau on the other side of the true point. A change of less than one mil will usually be sufficient. If it is changed one mil, each ray moves a distance equal to 1/1000 of its length in the proper direction. Thus the second estimated rays, which form the second chapeau, can readily be plotted.

The segments (arcs) on which the different intersections move can then be drawn in as straight lines connecting corresponding vertices of the two chapeaux. Their intersection is adopted as the true point, and is reliable to within a few decimeters. In case the segments form a small chapeau instead of intersecting at a point, as sometimes happens, its center can be adopted as the true point, as was done in intersection.

The following problem illustrates this method.

RELEVEMENT EXAMPLE.

INITIAL DATA.

Point	Co-ordinates X	Co-ordinates Y	Angles	Transit Readings.
A	161,454.0	79,241.0	APB 60° 12′ 56″	0° 00′ 00″
B	158,901.5	80,507.8	BPC 76° 34′ 09″	65° 12′ 56″
C	161,825.1	82,282.0	CPD 91° 09′ 39″	141° 47′ 05″
D	167,372.6	80,151.4	DPA 127° 03′ 16″	232° 56′ 44″
*P	161,950	79,960		

*Note: Co-ordinates of approximate point —P— are found graphically from a small scale diagram (Fig. 6), or a plane table sketch, or are scaled from a map.

COMPUTATION OF APPROXIMATE RAYS.

Item \ Line	PA	PB	PC	PD
△X	161,950 161,454.0 496.0	161,950. 158,901.5 3,048.5	161,950 161,825.1 124.9	161,950 167,372.6 5,422.6
△Y	79,960 79,241.0 719.0	79,960 80,507.8 547.8	79,960 82,282.0 2,322.0	79,960 80,151.4 191.4
Log △X	2.695482	3.484086	2.096562	3.734208
Log △Y	2.856729	2.738622	3.365862	2.281942
Log tan bearing	9.838753	.745464	8.730700	1.452266
Bearing	S 34°—36′—00″ W	N 79°—48′—47″ W	N 3°—04′—44″ W	N 87°—58′—42″ E
Y-azimuth of Approx. Ray ..	214°—36′—00″	280°—11′—13″	356°—55′—16″	87°—58′—42″
Transit Reading ...	0	65°—12′—56″	141°—47′—05″	232°—56′—44″
Y-azimuth of PA	214°—36′—00″	214°—58′—17″	215°—8′—11″	215°—01′—58″

COMPUTATION OF ESTIMATED ORIENTATION.

Line \ Item	Y-azimuth of P A	Length (scaled)	Weight	Product (214° omitted)
P A	214°—36′—00″	880	1	0°—36′—00″
P B	214°—58′—17″	3120	4	3°—53′—08″
P C	215°— 8′—11″	2320	3	3°—24′—33″
P D	215°— 1′—58″	5400	7	7°—13′—46″
Weighted Mean	215°— 0′—30″		15	15°—07′—27″

COMPUTATION OF DATA FOR LARGE SCALE DIAGRAM (Fig. 7).

Item \ Line	PA	PB	PC	PD
Mean Y-azimuth of PA	215°—0′—30″	215°—0′—30″	215°— 0′—30″	215°— 0′—30″
Transit Reading.....	0	65°—12′—56″	141°—47′—05″	232°—56′—44″
Estimated Y-azimuth.	215°—0′—30″	280°—13′—26″	356°—47′—35″	87°—57′—14″
Approx. Y-azimuth ..	214°—36′—00″	280°—11′—13″	356°—55′—16″	87°—58′—42″
Difference (d0)	+ 24′—30″	+ 2′—13″	— 7′—41″	— 1′—28″
d0 in mils..........	+7.26	+0.657	2.27	—0.436
Length (D) scaled...	880	3120	2320	5400
Distance (Q) to estimated ray	+6.39	+2.05	—5.27	—2.36
Distance (Q′) from 1st to 2nd estimated rays*	—0.44	—1.56	—1.16	—2.70

*Orientation decreased ½ mil to form 2nd Chapeau. All rays move to the left.

Using this data a large scale diagram of the vicinity of the approximate point is made. (See Fig. 7.) The approximate point

and the approximate rays radiating therefrom are platted first; then the first estimated rays, forming the first chapeau, as explained above; then the second estimated rays, forming the second (inverted) chapeau; the corresponding vertices of the two chapeaux are connected by straight lines (segments) whose intersection is

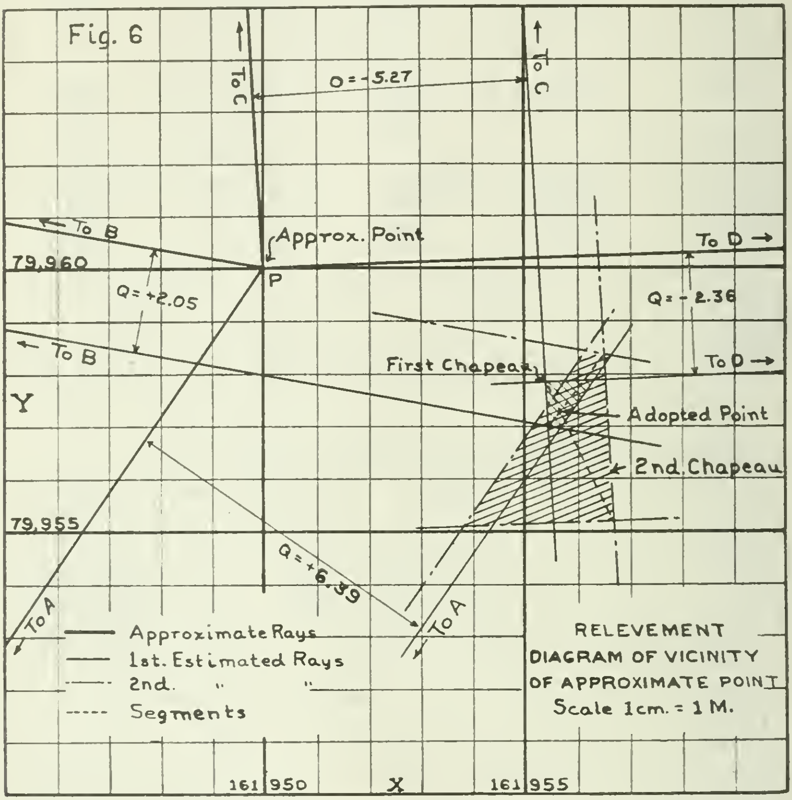

Fig. 7. Relevement. Diagram of Vicinity of Approximate Point

adopted as the true point. Its co-ordinates are scaled directly from the diagram as X = 161,955.7, Y = 79,957.3.

These methods are simple and accurate, and can be used rapidly. Furthermore, they are well adapted for use with co-ordinates, particularly when the quadrillage is based on Lambert's projection. It would seem as if they might also be used to advantage in surveys in the United States where latitudes and departures, or co-ordinates, are used.

Note: This article was prepared at the Coast Artillery Training Camp, Fort Monroe, Virginia, where these methods were taught to candidates for commissions in the Heavy Coast Artillery as a part of their training for overseas service. It has been approved by Colonel R. R. Welsheimer, Commandant of the training camp; Lt. Col. R. E. Guthrie, director of instruction, and Major E. A. Zeigler, senior instructor in Orientation, the course of study in which these and other survey methods are taught.

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*Tests of Plain and Reinforced Gypsum Specimens**

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To be presented October 13, 1919.

ALTHOUGH gypsum is one of the oldest of building materials and although a reinforced gypsum floor was among the earliest to receive the recognition of any official bureau in this country as a fireproof floor as the result of fire and load tests,[1] little exact information on the properties of gypsum or of reinforced gypsum has been available. So in order to obtain the information necessary for the intelligent use of gypsum in places for which it is suited, the tests described in this paper were undertaken.

This investigation extended intermittently over three years and with slight exception is divided in the presentation into three groups of tests arranged chronologically and designated by the year in which the tests were made. The difference in the conditions under which the different groups of tests have been made make it impracticable to present the test data in any other way.

General Statement. Pure gypsum completely hydrated has the chemical formula $CaSO_4$ $2H_2O$. When partially dehydrated it acquires the property of setting when water is brought into contact with it. The degree to which this property is present depends much upon the extent to which the dehydration has been carried. With the differences of opinion which exist as to the extent of the setting ability of gypsum at various stages of dehydration this paper is not concerned.

In the following pages the terms "first settle" and "second settle" gypsum are used. The following statement indicates roughly the distinction between the two materials. When a charge of ground gypsum is subjected to a steadily increasing temperature,[2]

*For Index, see page 163.

**Based on these tests standards for design of reinforced gypsum beams have been prepared and are presented in the report of Committee C-11, Amer. Soc. Testing Material, 1919.

1. See Engineering News, Volume XXXIV, p. 333, Nov. 11, 1895.

2. See pp. 55 and 59, Bulletin No. 11, Oklahoma Geological Survey, "Gypsum and Salt of Oklahoma," by L. C. Snider; and p. 107, Mines Branch, Bulletin No. 84, "Gypsum Deposits of the Maritime Provinces," Mines Department, Ottawa, Canada.

it goes through alternate stages of quiescence and of boiling due to the more rapid ejection of water as steam at certain stages than at others. Gypsum whose calcination stops with the end of the first boiling stage is termed here "first settle gypsum," and gypsum whose calcination stops with the end of the second boiling stage is termed "second settle gypsum." The temperature reached at the various stages of boiling and quiescence and the amount of the water of crystallization which is driven off depend largely upon the rate of rise in temperature during the calcination process. Generally speaking, first settled calcined gypsum may be said to have three-fourths of the water crystallization driven off and second settle gypsum to have a larger amount driven off.

Various terms, such as plaster, plaster of Paris and stucco have been applied to gypsum. Here the terms calcined gypsum and hydrated gypsum are applied to gypsum which has been calcined and to gypsum which has been rehydrated after having been calcined. The term gypsum may designate either as indicated by the context.

Acknowledgment. The 1914 tests were made in the laboratory of applied mechanics of the University of Illinois, and the 1915 tests were made in the structural materials testing laboratory of Lewis Institute, Chicago. Acknowledgment is made to these institutions for the facilities and co-operation afforded.

The 1916-17 tests were conducted in the laboratory of the United States Gypsum Company in Chicago, for whom all the tests were made.

Although the investigation has been made for commercial reasons it has been carried out in a scientific manner for the purpose of obtaining fundamental data in a new field. Acknowledgment is made to officials of the United States Gypsum Company, who have supported this work.

1914 TESTS

Scope of Tests. This group includes tests to determine compressive strength and modulus of elasticity of gypsum cylinders of two sizes and having different percentages of water and retarder. Tests were made also of beams and of bond (pull-out) specimens.

Materials and Specimens. Three specimens of each kind were made and tested. All the specimens of this series were made from first settle calcined gypsum from the Fort Dodge Mill of the United States Gypsum Company. The specimens generally were stored for ten days before testing. The storage room was not always warm and the importance of thorough drying in order to secure high strength was not fully appreciated at this stage of the investigation. It is known that the specimens were not fully dry when tested and it seems that they probably were about 50 per cent dry.

The compression specimens were cylinders of two sizes, 6 in. in diameter by 12 in. long and 8 in. in diameter by 16 in. long. The specimens were molded upon a plate glass surface to furnish

a true face on the bottom of the specimen. Another piece of plate glass was placed on top of the mold to form a true upper face. In some cases, especially with the cylinders having more than 40 per cent of water, the loss of material by leakage caused a falling away from the upper plate so great as to hollow out the top of the specimen, and it was necessary to form a new surface by applying freshly mixed dental plaster.

The plain beams were 6 in. square in cross section, 18 in. long and were molded in steel forms. They were used to determine the

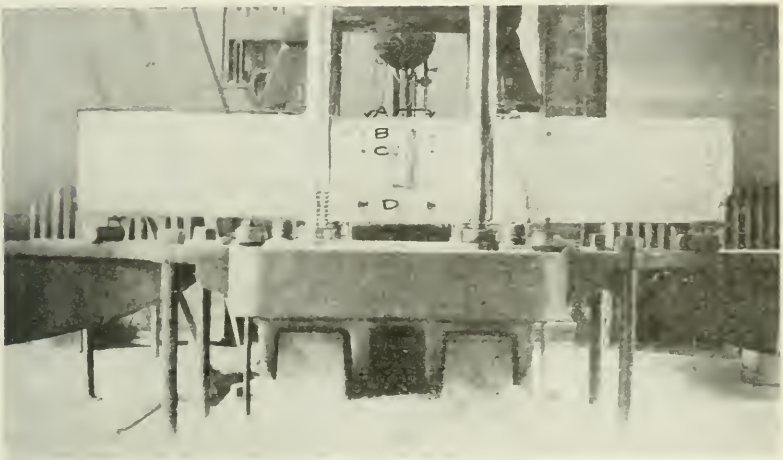


Fig. 1. View of 6-ft. Rectangular Beam in Testing Machine

modulus of rupture of the gypsum. The rectangular reinforced beams were all 8 in. by 12 in. in cross section by 6 ft. 6 in. long, and the steel was placed at a depth of 10 in. from the upper surface. These beams were made in wooden forms previously used in making reinforced concrete beams. The inner surface of the forms had previously been painted to reduce the absorption of the water from the mixture. For the same reason the forms were wetted previous to the making of each specimen. The reinforcement was straight for all the beams. For one beam anchor plates were furnished when it was found that failure was occurring by slip of bars in other cases.

Methods of Testing. All the specimens were tested in a screw-power testing machine of either Olsen or Riehle manufacture. Care was used to see that the ends of the cylinders had a uniform bearing either by casting to a plane surface or by surfacing with dental plaster.

For the cylinder tests the specimen was placed in the testing machine with the lower surface in direct contact with the lower platen of the machine. Upon the upper surface a steel plate 1 in. thick was placed and upon this a spherical bearing block. The

instrument used in measuring the deformation of the cylinder indicated twice the average deformation within the gage length on a median plane of the cylinder. It was sensitive to a movement of 0.0001 in. The gage length on the 8-inch by 16-inch cylinders was 10 in. and that on the 6-inch by 12-inch cylinders was 7½ in.

In making a bond test the specimen was placed upon the top stationary platform of a 100,000-pound Riehle testing machine with the free end of the imbedded bar projecting downward through

Table 1. Compressive Strength and Modulus of Elasticity of Gypsum

Size of Cylinders Inches	Per Cent Water	Per Cent Retarder	Age, days	Average Strength lb. per sq. in.	Modulus of Elasticity lb. per sq. in.	
					Initial	Final
		First Settle Gypsum: Fort Dodge, Iowa				
8x16	35	0	11	775	775,000	338,000
8x16	40	0	11	491	438,000	247,000
8x16	50	0	10	221	160,000	97,000
8x16	60	0	10	67	62,000	35,000
6x12	35	0	1	857	....	....
6x12	35	0	11	759	525,000	328,000
6x12	40	0	11	595	425,000	282,000
6x12	50	0	11	256	198,000	128,000
6x12	60	0	11	194	138,000	72,000
*8x16	30	0.10	10	929	910,000	500,000
*8x16	30	0.20	10	646	840,000	470,000
*8x16	30	0.30	10	770	640,000	350,000
8x16	35	0.10	10	918	793,000	447,000
8x16	35	0.20	10	742	687,000	410,000
8x16	35	0.30	10	636	697,000	380,000
8x16	40	0.10	10	643	508,000	288,000
8x16	40	0.20	10	405	495,000	198,000
8x16	40	0.30	10	322	523,000	202,000
8x16	35	0.14	1	783	937,000	528,000
8x16	35	0.14	2	794	673,000	437,000
8x16	35	0.14	4	752	682,000	447,000
6x12	35	0.14	10	869	753,000	443,000
6x12	35	0.30	110	1,350	1,277,000	1,227,000
6x12	35	0.15	182	2,087	....	....
		Second Settle Gypsum: Alabaster, Michigan				
6x12	35	0.10	11	1,276	754,000	484,000
6x12	35	0.15	11	1,186	826,000	483,000
6x12	35	0.20	11	1,0[illegible]5	823,000	481,000
6x12	40	0.1	10	820	660,000	400,000
6x12	35	0.10	..	1,753	....	....

* One test each; all other values are averages of three tests.

the opening in the platform. The projecting bar was caught by the grips in the moving head of the machine, and was pulled downward until the maximum load was reached. The amount of slip of the bar through the gypsum was measured by an Ames Dial[3] apparatus attached to the specimen.

The plain beams (6 by 6 by 18 in.) were loaded at the center of a 16-inch span. No measurements except maximum load were taken. The reinforced rectangular beams (8 by 12 in. by 6 ft. 6 in.) were tested in a 200,000-pound Olsen testing machine. The span used in testing was 6 ft. and the load was applied at the one-third

3. See instrument and yoke illustration on page 18 of Bulletin No. 71 of the University of Illinois engineering experiment station, by D. A. Abrams.

points of this span. Fig. 1 shows a beam in the machine. In the beams of the first series the load was applied generally in increments of 1,000 lb. and strain gage readings of deformation were taken for each stage of the loading on the reinforcing bars and at three different depths on the gypsum at the center of the span.

Test Results. The effect of the amount of water used in mixing on the compressive strength is shown in Table 1 and Fig. 2. Fig. 2 is discussed on page 426.

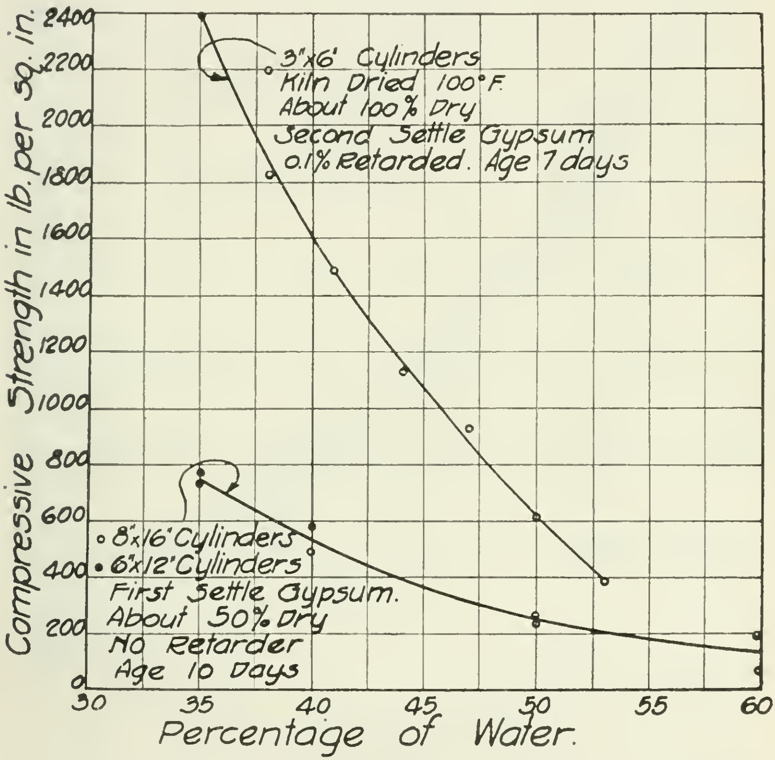


Fig. 2. Effect of Percentage of Water on Compressive Strength of Hydrated Gypsum

Fig. 3 shows the relation between the percentage of gaging water used and the unit deformation corresponding to various unit stresses. Typical stress strain curves for specimens under various conditions are shown in Fig. 4. Attention is called to the straightness of the curve for the dry specimen.

Fig. 5 shows the decrease in the modulus of elasticity due to an increase in the percentage of gaging water. The moduli of elasticity also are given in Table 1.

The results of the tests of the plain beams are shown in Table 11. The average modulus of rupture in tension was 377 lbs. per sq. in.

The results of the reinforced beam tests are given in Table 2. The appearance of the beams after tests is indicated in Fig. 6.

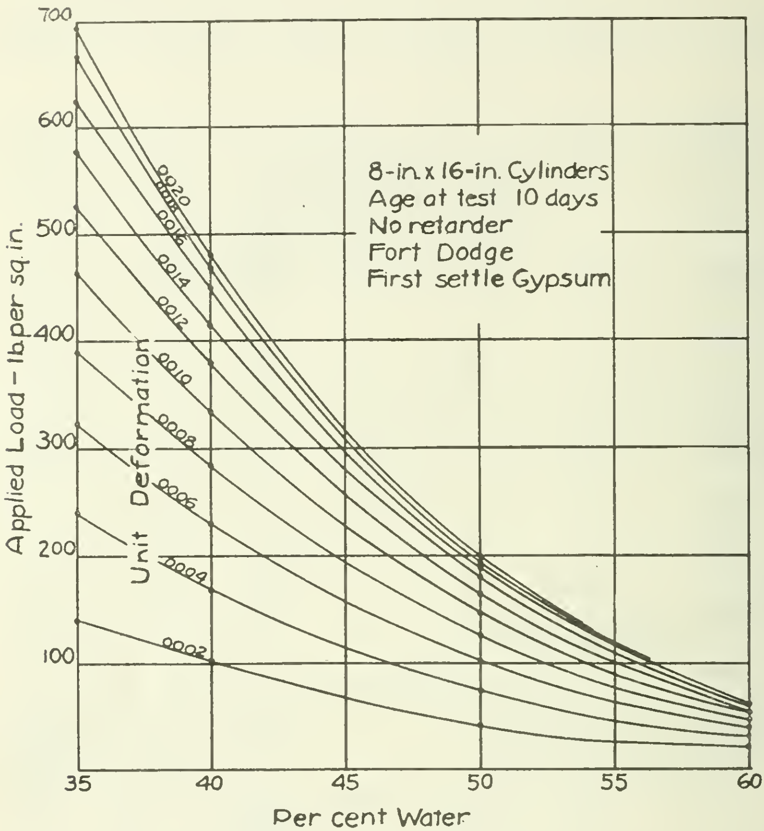


Fig. 3. Relation Between Percentage of Gaging Water, Unit Stress and Unit Strain.

These views show that usually only one or two cracks formed in each beam. These cracks were usually in the outer thirds of the span and seem to have been due to a failure in bond. They occurred suddenly but did not cause complete failure, though after their occurrence it was impossible to get the beam to carry any increased load. An exception to this statement is made for the case of beam No. 4-6, the bars of which were anchored by means of plates at their ends to prevent complete failure due to slipping of the bars. For this beam the load fell off from 8,275 lbs. to 8,175 lbs. at the time of the appearance of the first cracks, but

with continued operation of the machine the load rose to 14,275 lbs. At the level of the reinforcement the cracks in most of the beams were so nearly vertical that it is not likely that diagonal tension was an important factor in their development. The behavior of

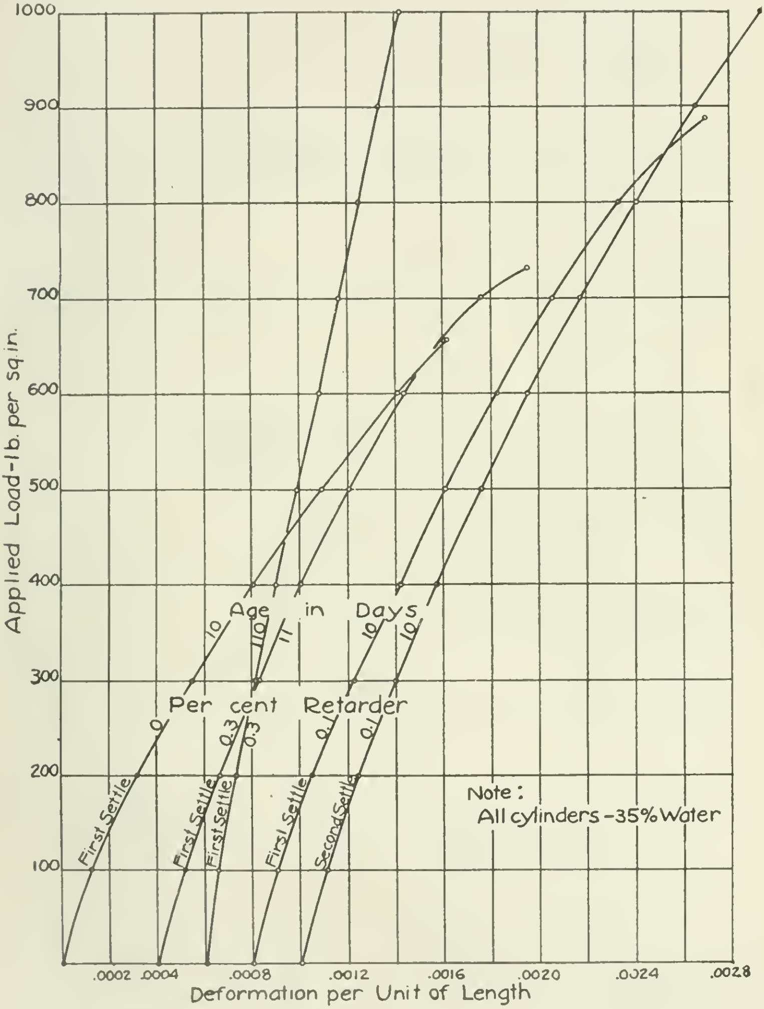


Fig. 4. Stress Strain Curves for Gypsum Specimens under Various Conditions

beam No. 4-6 further indicates that diagonal tension was unimportant as a factor in causing the failure of any of the beams. This beam in which the ends of the bars were anchored by means of nuts and plates was exactly like beam No. 4-5 in percentage of reinforcement and size of bars. It carried 14,275 lbs. while

Table 2. Reinforced Gypsum Beams; Results of 1914 Tests

Beam No.	Maximum Load lb.	Per Cent of Water	Reinforcement		Shearing Stress $=\frac{V}{bjd}$ lb. per sq. in.	Bond Stress lb. per sq. in.	Tensile Stress in Steel lb. per sq. in.		Tensile Stress in Gypsum lb. per sq. in. (Calculated)	Compressive Unit-Deformation in Gypsum at Upper Fibre	Depth of Neutral Axis (Inches) Observed
			Per Cent	No. and size of bars			Calculated	Observed			
4-1	5,875	35	.49	2½ round	36	(a) 109 (d) 57	(a) 18,600 (b) 10,400 (c) 8,500	10,000	(b) 230 (c) 200	.00078	4.2
4-2	6,275	35	.49	2½ round	39	(a) 116 (d) 72	(a) 19,900 (b) 11,100 (c) 9,000	11,200	(b) 246 (c) 214	.00065	7.0
4-3	5,275	40	.49	2½ round	33	(a) 98 (d) 57	(a) 16,700 (b) 9,300 (c) 7,600	8,400	(b) 207 (c) 179	.00084	7.2
4-4	5,975	40	.55	4⅜ round	37	(a) 111 (d) 49	(a) 18,900 (b) 10,500 (c) 8,600	12,000	(b) 234 (c) 204	.00093	7.3
4-5	7,375	35	.55	4⅜ round	46	(a) 136 (d) 53	(a) 23,400 (b) 13,000 (c) 10,600	12,000	(b) 289 (c) 250	.00086	6.7
4-6	14,275	35	.55	4⅜ round	89		(a) 58,200 (b) 25,200 (c) 20,600	30,000	(b) 559 (c) 485	.00244	6.4

(a) Tensile strength of gypsum neglected, j taken as .86.

(b) Tensile strength of gypsum considered; k taken as 0.7, from average of observations shown in Fig. 8. Resulting value of n found to be 75.

(c) Tensile strength of gypsum considered; n taken as 53 from results of cylinder tests. Resulting value of k found to be 0.67.

(d) Av. bond stress calculated on basis of observed steel stress and length of embedment between crack and end of beam.

beam No. 4-5 carried only 7,275 lbs. At the load of 14,275 lbs. beam No. 4-6 had not completely failed, but the load was increasing so slowly that it is not likely that it could have carried much more.

The observed unit deformations at the top and the bottom of the beam plotted against applied loads are shown in Fig. 7 and the

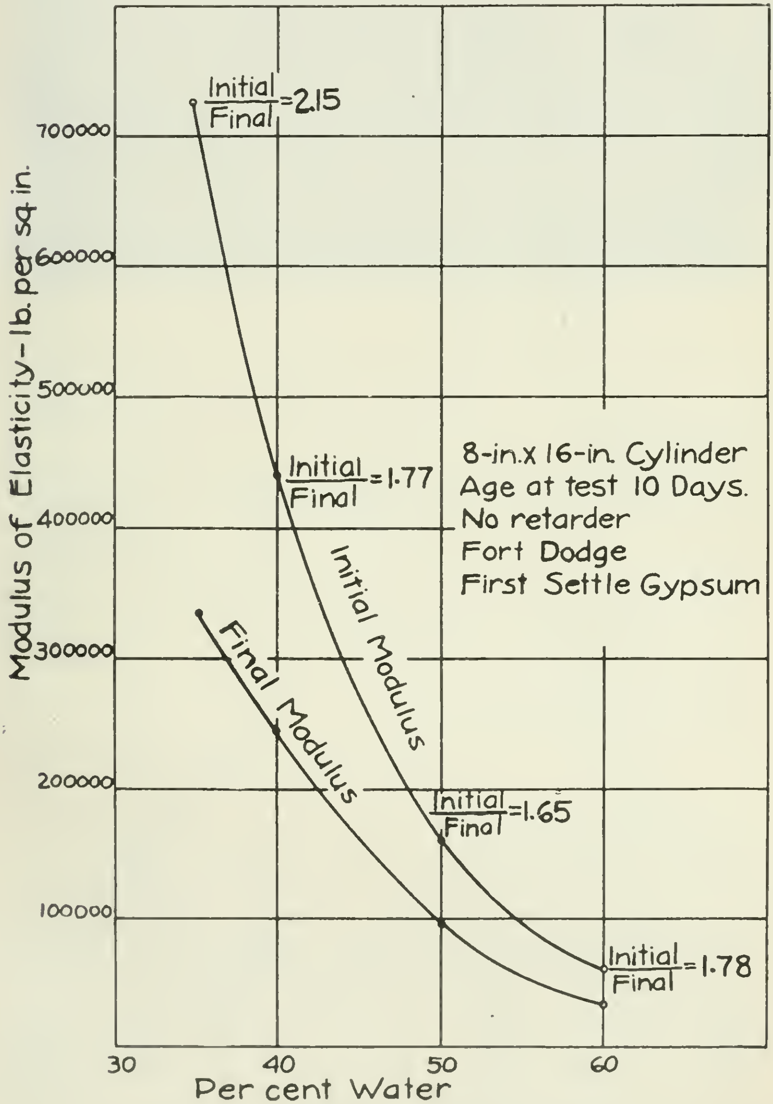


Fig. 5. Relation Between Percentage of Gaging Water in Gypsum and Modulus of Elasticity

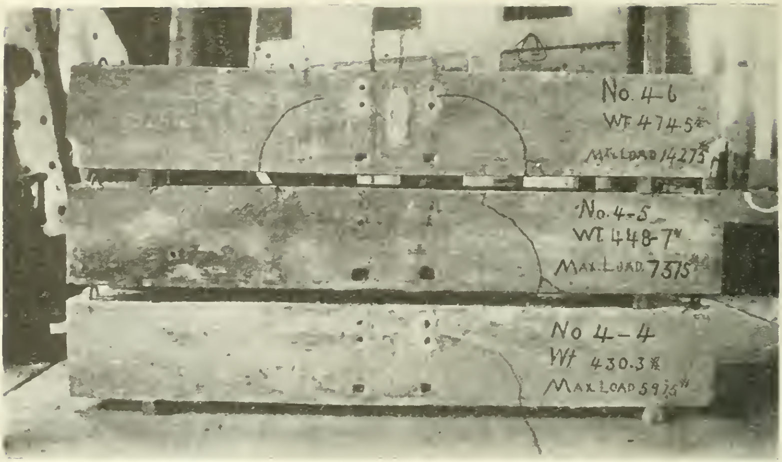


Fig. 6. View of 1914 Beams After Test

positions of the neutral axis of the several beams as deduced from the unit deformation observed at several elevations on the beams are given in Fig. 8.

The most striking features of the results given in Table 2 are the low bond stresses at failure, the unusual depth of the neutral and the low steel stresses as compared with the steel stresses cal-

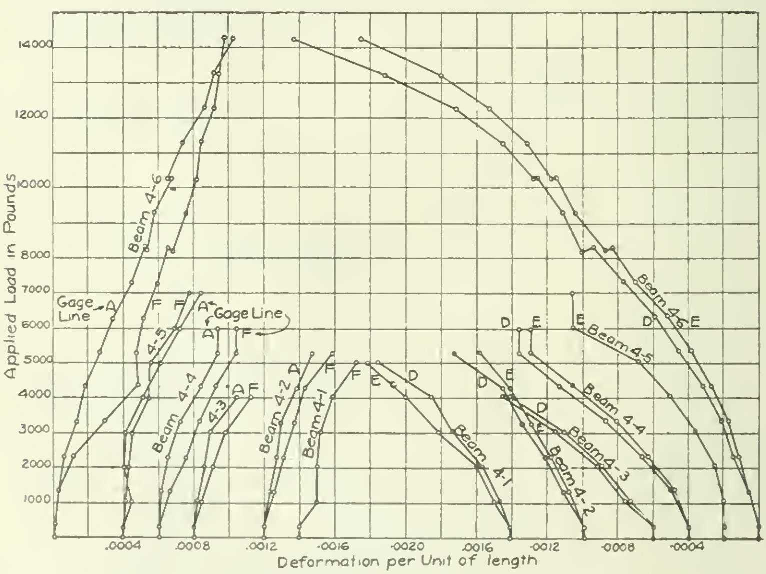


Fig. 7. Load-Strain Curves; Top and Bottom of Beams of 1914 Test

culated by the methods ordinarily used for concrete beams. The computed steel stresses are tabulated under the designation (a). The low bond strengths found are in accord with the results of

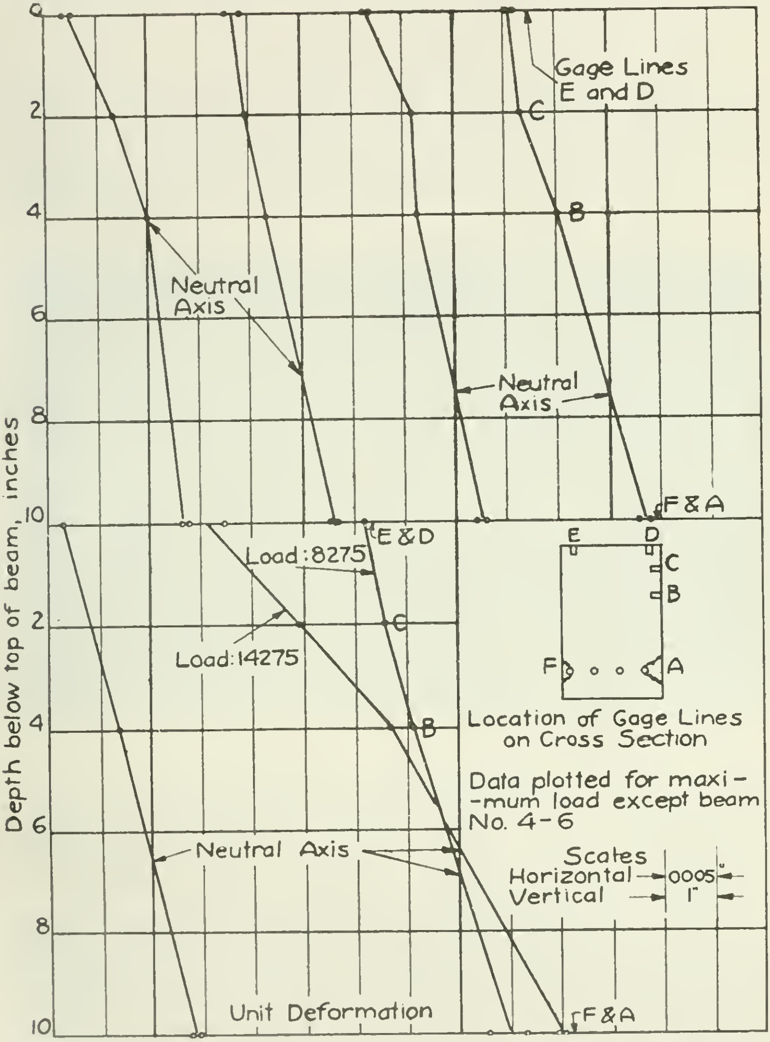


Fig. 8. Position of Neutral Axis from Measured Deformation; Beams of 1914 Tests

the pullout tests reported in Table 3. The low shearing stresses are not of significance since none of the beams failed by diagonal tension.

The low positions of the neutral axis shown in Fig. 8 can be partially accounted for by the assumption that the gypsum did not

fail in tension and that the ratio, n, of the modulus of elasticity for the steel to that of the gypsum was very high. In none of these beams were any cracks found within the middle one-third of the span although careful examination for cracks was made.

1915 TESTS

Purpose of Tests. The main purpose of this group of tests was to obtain information on the shearing strength of reinforced gypsum beams though certain tests for other purposes were made.

Specimens and Testing. The specimens of this group consisted of 6-inch by 12-inch compression cylinders, 8-inch by 8-inch

Table 3. Bond Strength; Results of 1915 Pull-Out Tests.

Specimen No.	Date Made	Age at Test days	Size of Bar inches	Kind of Bar	Per cent of Water	Bond Stress lb. per sq. in. At First Slip	At Slip of 0.001 inch	At Max. Load
2-7	3-10	12	⅝	Cor.	38.1	76	133	209
2-9	3-10	12	⅝	Cor.	38.0	58	140	218
					Average	67	136	213
2-8	3-10	12	⅝	Plain	38.1	25	105	122
2-10	3-10	12	⅝	Plain	38.0	44	75	98
					Average	35	90	110
2-13	3-11	11	½	Plain	35.0	81	119	178
2-14	3-11	11	½	Plain	35.0	64	190	222
					Average	72	154	200
2-15	3-11	11	½	Plain	40.8	63	108	134
2-16	3-11	11	½	Plain	40.8	39	116	146
					Average	51	112	140
2-17	3-11	11	½	Cor.	35.0	52	110	440
2-18	3-11	11	½	Cor.	35.0	..	20	409
					Average	..	65	420

Specimens 2-7, 2-8, 2-9 and 2-10 were made from first settle gypsum; all others from second settle gypsum.

All bars used were round.

bond specimens, and reinforced beams exactly the same in cross section and span as those of the 1914 tests, and reinforced T-beams, 17 ft. long.

The making of the cylinders and beams was as described for the 1914 tests.

The bond specimens consisted of cylinders of gypsum 8 in. in diameter and nominally 8 in. long, each having a one-half-inch steel bar embedded axially the full length of the specimen and projecting at one end 16 in.

After the gypsum had been placed in the mold and before it had set, the bar was inserted in such a position that its longitudinal axis coincided with the longitudinal axis of the cylinder. In the position of making the specimen the bar extended 16 in. upward from the gypsum specimen. In the position for testing, it extended 16 in. downward from the gypsum.

The reinforcement of the rectangular beams consisted of plain and corrugated bars, some of which were used straight and some

of which were looped at the ends for anchorage. Reinforcing units also were made up from Kahn "rib metal." A unit consisted of two parts, each having two horizontal reinforcing bars, an upper and a lower, connected by web members. Each part was sheared from a single piece of rolled mild steel and expanded so as to give the web members an angle of about 60 degrees with the horizontal. The two parts of the necessary length were placed side by side and welded together, the welds coming at three points on the bottom reinforcing bars and at two points on the upper bars. They were so arranged that web members of the two halves inclined in opposite directions relatively to a section across the unit at any point.

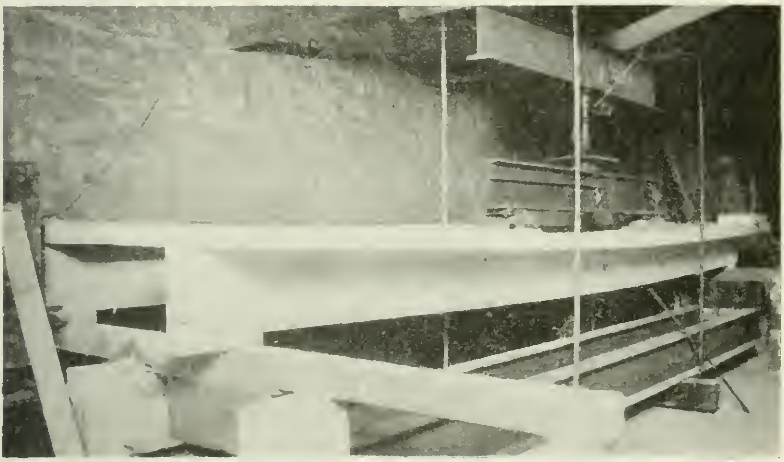


Fig. 9. View of Apparatus Used in Testing T-Beams of 1915 Tests

The T-beams were made at Lewis Institute, Chicago, from second settle gypsum calcined at Alabaster, Mich. The water used was 35 per cent of the total weight of the water and gypsum and the retarder was 0.1 per cent of the weight of the calcined gypsum.

Wooden forms were used for the T-beams. Usually three batches, each containing 282 lb. of calcined gypsum and 152 lb. of water were used in making a single beam. One or more control cylinders were made from each batch of gypsum. The amount of retarder used was sufficient to prevent any setting before the entire beam had been poured and thus the formation of surfaces of cleavage was avoided. In placing the gypsum, care was used to secure a proper filling around the reinforcement. Generally good results in this respect were obtained. The forms were removed about three hours after the beams were poured. In order to determine when the T-beams had dried out sufficiently for testing, each beam was weighed at intervals between the time of making and the time of testing.

Table 4. Reinforced Gypsum Beams; Results of 1915 Tests

Beam No.	Reinforcement			Depth to Steel, inches	Date Made, 1915	Load at First Crack, lb.	Maximum Load, lb.	Calculated Stresses at Maximum Load lb. per sq. in.				Manner of Failure
	Description	Area, sq. in.	Per Cent					Shear $\frac{V}{bjd}$	Bond $\frac{V}{mojd}$	Tension $= \frac{M}{Ajd}$	Compression $\frac{2\ pf}{k}$	
4-7	Four ⅝-in. plain round	1.22	1.49	10.20	3-9	15,200	20,000	157	160	24,800	1,340	DT and C
4-8	anchored with nuts	1.22	1.45	10.5	3-9	16,050	21,000	160	163	25,500	1,370	C
4-9	and plates	1.22	1.45	10.5	3-9	12,000	14,100	106	108	17,000	913	
4-10	Three ⅝-in. plain round	1.28	1.74	9.2	3-9	9,200	21,900	194	145	29,000	1,750	T.DT and C
4-11	and two Kahn units. An-	1.28	1.60	10.0	3-10	14,000	19,000	153	114	22,800	1,320	B and DT
4-12	chored by attached plates	1.28	1.58	10.1	3-10	15,200	22,500	179	135	27,000	1,520	DT
4-13	Two rib-metal units:	0.36	0.46	9.9	3-9	7,000	9,560	70	115	37,500	960	B and T
4-14	no anchor-	0.36	0.46	9.8	3.9	7,250	10,070	75	123	40,000	1,020	T and B
4-15	age	0.36	0.46	9.9	3-10	6,000	11,200	84	137	44,000	1,125	T no slip
4-16	Two rib-metal units:	0.36	0.46	9.9	3-10	6,280	10,400	76	125	41,500	1,040	T
4-17	ends looped with U-hooks	0.36	0.45	10.0	3-12	8,000	10,700	78	127	41,500	1,020	T
4-19	Four ⅝-in. cor. round,	1.22	1.49	10.2	3-18	16,000	16,000	126	129	19,700	1,060	B and DT
4-21	no anchorage	1.22	1.49	10.2	3-16		16,000	126	129	19,700	1,020	B and DT
4-22	Four ⅝-in. plain	1.22	1.47	10.4	3-16		12,400	97	97	14,900	800	B
4-23	round, no anchor-	1.22	1.49	10.2	3-18	14,100	14,100	111	113	17,400	940	B
4-24	age	1.22	1.48	10.3	3-18	15,800	15,800	123	126	19,200	1,040	B
*4-26	Four ⅝-in. cor. round, no anchorage	1.22	1.48	10.3	3-22	23,980	23,980	187	191	29,200	1,580	DT

*Second settle gypsum, all others first settle gypsum.

Notes.

Age at test, 10 days for all beams, except 4-9, 4-11 and 15, which were 97, 94 and 94 days respectively.

Each Kahn unit has a total right cross sectional area of web reinforcement of 0.012 sq. in.

The web members were inclined at an angle of about 60° and spaced 8 inches apart.

In "Manner of Failure": B = bond, C = compression, T = tension, DT = diagonal tension.

Weight of water, 38.1% of combined weight of water and calcined gypsum except beams 4-21, 4-22 and 4-26 in which it was 37.5, 35.0 and 35.0% respectively.

Table 5. Reinforced Gypsum T-Beams; Results of 1915 Tests

Beam No.	Reinforcement: Description	Reinforcement: Area, sq. in.	Age at Test, days	Load at First Crack, pounds	Observed Steel Stress at First Crack, lb. per sq. in.	Maximum Loads, pounds	Stresses at Maximum Load, lb. per sq. in.: Vertical Shear	Horizontal Shear	Bond	Tension: Calculated	Tension: Observed
4.1-1.1	Three 5/8-in. cor. round; straight	0.92	20	5,250	19,000a	7,850	87	153	74	29,200	28,600
4.1-1.2		0.92	17	6,300	22,000	6,300	70	123	60	24,400	23,000
4.1-2.1	Two 3/8-in. cor. round and one 1/4-in. cor. round, all bars straight	0.27	19	3,200	31,500b 38,000c	3,700	41	42	70	48,000	d
4.1-2.2		0.27	17	3,150	25,000b 29,000c	3,750	42	42	71	48,000	d
4.1-3.1	Two 5/8-in. cor. round, looped at ends for anchorage	0.61		Accidentally broken before test.							
4.1-3.2		0.61	15	6,650	24,000	6,650e 7,550f	74 86	102	95	39,500 44,800	36,000 41,000

Notes

a. This crack did not extend higher than the level of the reinforcement before failure.
b. Under load point (one-third point of span).
c. At center of span.
d. Had passed yield point.
e. Load indicated by dial.
f. Corrected load.

A view of the apparatus used for testing the T-beams is given in Fig. 9. The load was applied by means of a 20-ton screw jack which was placed at the center of the span. The I-beam on which the jack rested was used for applying the load at the one-third points of the span of the T-beam. The load was measured by means of the dial gage shown in Fig. 9, attached to this I-beam. This dial indicated the deflection of the elastic curve of the I-beam from a tangent at the support of the I-beam. Previous to the tests the I-beam and dial apparatus were calibrated, so that the load corresponding to a given deflection of the pointer attached at the support was known. Precautions were taken to insure the application of the load in the same way each time so that the deflection was always the same for a given load.

Test Results. The results of the cylinder tests for this group are combined with those for the 1914 tests. (See Table 1 and Fig. 4.) The results of the bond tests are shown in Table 3. The results of the beam tests are given in Tables 4, 5 and 6.

In six of the fourteen rectangular beams, diagonal tension was evident in the failure. Fig. 10 shows a typical diagonal tension crack. In all but two of these six beams some other form of failure was in evidence at the same time. Slip of bars was present in all the beams having no anchorage, and in such cases it

Table 6. Reinforced Gypsum T-Beams; Results of 1915 Tests (Continued)

Beam No.	Load Considered, pounds	Moment Arm, inches	2 Ratio of Assumed to Actual Moment Arm	1 Compressive Stress in Control Cylinders. lb. per sq. in.	Calculated Compression at Upper Fibre, lb. per sq. in.	Modulus of Elasticity of Gypsum. lb. per sq. in. From T-Beams	From Cylinders
4.1-1.1	7,300	8.82	1.03	1,510	454	250,000	965,000
4.1-1.2	6,300	9.00	1.01	1,150	...	367,000	1,095,000
4.1-2.1	2,200	9.29	0.98	650	153	278,000	1,180,000
4.1-2.2	3,150	9.42	0.97	710	255	412,000	1,450,000
4.1-3.1			Accidentally broken before test.				
4.1-3.2	4,950	8.81	1.04	1,170	284	256,000	1,050,000

1 Compressive stress in control cylinders at same unit deformation as that developed in upper fibre of T-Beam.
2 Assumed moment arm = d — ½ t.

is probable that the diagonal tension failure was promoted by this slip. The highest shearing stress, 187 lb. per sq. in., was carried by beam No. 4-26, made of second settle gypsum. This beam failed by diagonal tension alone.

In no beam of first settle gypsum did failure occur by diagonal tension alone at a shearing stress less than 179 lb. per sq. in., and in no beam which failed at a shearing stress less than 147 lb. per sq. in. did diagonal tension enter even as a secondary phenomenon of failure.

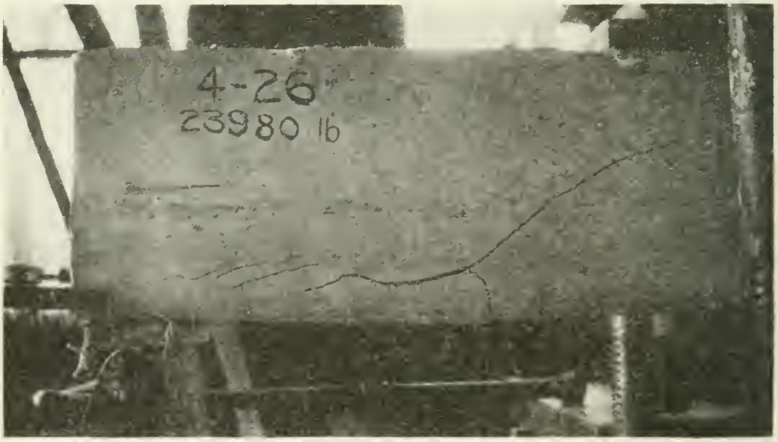


Fig. 10. Typical Diagonal Tension Crack in Rectangular Beam

A comparison of beams 4-7 and 4-9 with beams 4-10 and 4-17 does not indicate that the presence of the rib metal units in the latter beams increased the shearing strength over that of the beams without the units. Since the cross sectional area of the web reinforcement was very small this result is not surprising.

At the maximum load for two beams there were indications of local failure by diagonal compression. This is a phenomenon unknown in tests of reinforced concrete beams of these proportions and was brought about, probably, by a combination of the compres-

sion caused by the bearing of the anchor plate against the end of the beam with a high shearing stress and a low compressive strength in the gypsum at this age.

The ultimate strength of beams with about 1.5 per cent reinforcement and, having bars anchored to prevent bond failure, was fairly well balanced between tension, diagonal tension and compression. This is indicated by the manner of failure and by the computed stresses at maximum load.

Beams 4-9, 4-11 and 4-15 were left until they were three months old before testing. Beams 4-9 and 4-11 were made with bars anchored at the end by means of nuts and plates and the purpose in their design was to determine the diagonal tension strength of gypsum beams in which the bars were prevented from slipping. At the time of the test it seemed more desirable to find out if the bond strength had increased in the interval than to determine as to the increase in the diagonal tensile strength, and accordingly the nuts were loosened before the test.

In both beams, 4-9 and 4-11, end slip occurred as nearly as could be observed at the same instant that the first diagonal tension crack formed, and it is not apparent whether the slipping caused the crack to appear or whether it was a result of the formation of the cracks. The diagonal tension cracks occurred with a clear sharp report, and in one case three of them lying close together and almost parallel occurred simultaneously. The diagonal tension cracks occurred at both ends of the beams and were unusually straight, extending from a point at the level of the reinforcement almost directly toward the top of the beam at the load-point. The appearance and the manner of occurrence of these cracks were such as to indicate that the gypsum possessed great uniformity of structure and of strength.

Phenomena of Tests of T-Beams. In all the tests careful examinations for cracks were made at frequent intervals and no cracks were found until the deformations in the reinforcement were unexpectedly high. In searching for cracks an electric light was used, and as the beams were white and smooth it is likely that cracks were found soon after they formed. In two tests none were found before failure, and in a third only a small crack which did not extend above the reinforcement. The relatively high tensile strength and low modulus of elasticity of gypsum will help to account for these phenomena. The load and steel stress at which the first cracks occurred are given in Table 5. In the beams having light reinforcement (0.27 sq. in.) the yield-point stress in the steel was reached, and after this the beams held a load which remained about constant with continued operation of the loading jack. In the meantime the deflection and deformations kept increasing and the cracks opened up, becoming quite wide. Although the test was not always continued until the beam collapsed, failure was considered to have occurred when the steel had developed its yield-point

stress, since it was not possible to make the beam carry a load larger than the one which caused this stress.

In beams with heavier reinforcement (0.61 and 0.92 sq. in. of steel) cracks were not developed before the maximum load except in beam No. 4.1-1.1, and in this case the cracks extended only to the level of the reinforcement. In the beam with 0.61 sq. in. of steel (2 ⅝-inch bars) the bars were hooked at the ends and no measurements of slips were taken. In the beams with 0.92 sq. in. of steel (3 ⅝-inch bars) the bars were straight and slip measurements were taken. In beam 4.1-1.1 slip apparently began at a load 4,800 lb. and increased to a maximum of 0.004 in. at the one end at the maximum load. The fact that no cracks could be found raises a question as to whether slip actually occurred. In the next beam tested, 4.1-1.2, the slip began at a load of 4,000 lb. A little later in the test it was found that these readings were being affected by the method of attaching the instruments. At a load of 4,800 lb. the defect was corrected and the instrument reset at zero. After this no further slip occurred during the test. This leaves still more in doubt the question as to whether or not slip actually occurred in the previous case.

The beams having 0.27 sq. in. of reinforcement failed gradually by tension in the steel. Those having more reinforcement failed by stripping of the gypsum from the bottom of the reinforcement, and the failure was complete and without warning. It seems unlikely that bond stress or diagonal tension, as they ordinarily occur, had much influence in causing failure in these beams, since the shearing stresses and bond stresses were much lower than were found in the rectangular beams which failed in diagonal tension or bond. None of these T-beams developed a shearing stress greater than 87 lb. per sq. in., while of the rectangular beams of the 1915 tests (Table 4) no beam failed primarily by diagonal tension at a shearing stress less than 179 lb. per sq. in.

The highest bond stress developed was 95 lb. per sq. in. The 1915 beam tests indicate that this is not sufficient to produce bond failure with corrugated bars. The indications of the end slip readings and the non-formation of cracks are opposed to the conclusion that failure was due primarily to slipping of reinforcing bars.

In the beams with the larger amounts of reinforcement the sum of the diameters of the bars was so great as to leave a comparatively small cross sectional area of gypsum connecting the portion of the web below the bars with the portion above the bars. This resulted in a high horizontal shearing stress at the level of the reinforcement.

In addition to this the stiffness of the ⅝-inch bars probably was sufficient to develop a considerable tendency toward stripping from the bottom of the beam. Altogether it seems likely that the real cause of failure in the beams having more than 0.27 sq. in of reinforcement was the tensile stress set up by a combination of the high horizontal shearing stress at the plane of the bars and

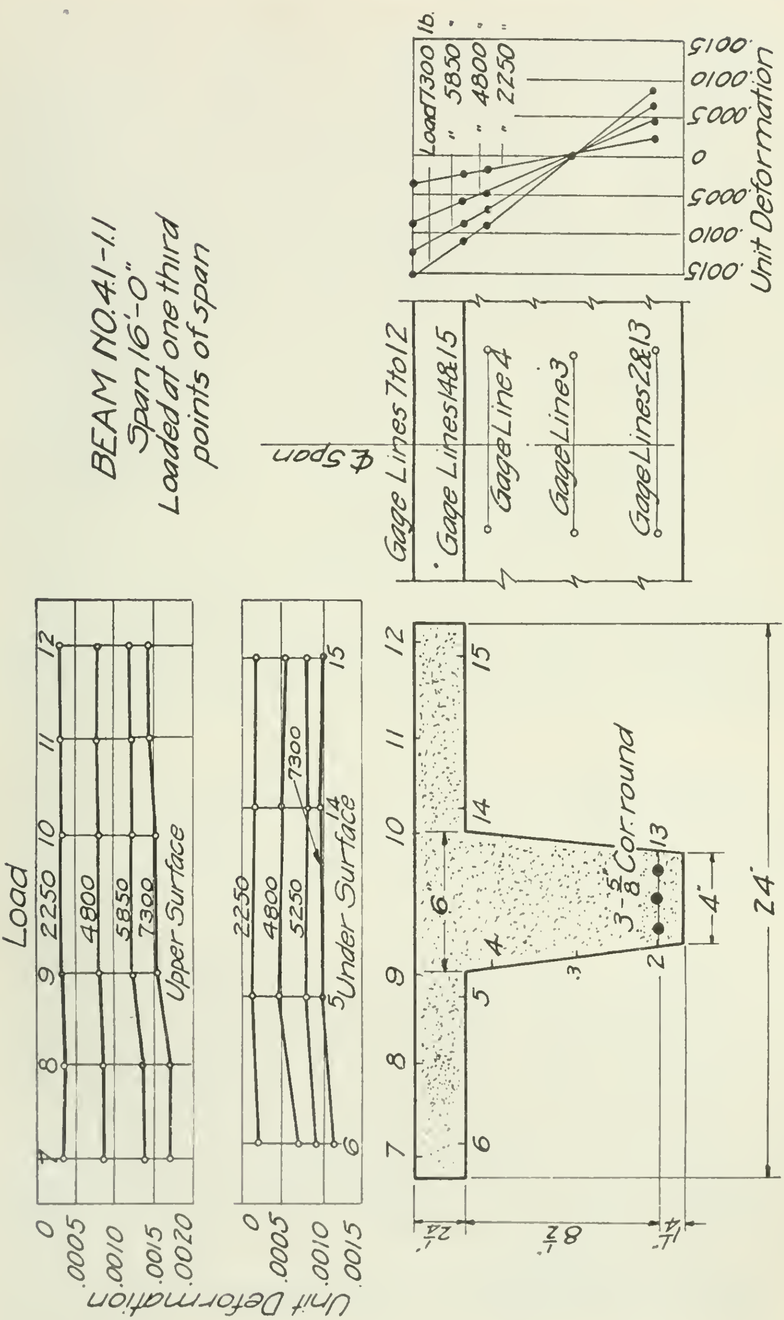


Fig. 11. Position of Neutral Axis and Distribution of Compression Over Width of Flange in T-Beam

the stripping action of the bars. The completeness of the failure probably was due to the entire absence of anchorage of the bars after stripping of the bars had occurred.

Compressive Stresses in T-Beams. As shown in Fig. 11 the compressive stress was distributed across the flange of the beam with considerable uniformity at all stages of the tests. This test is representative of all the beams.. The others are omitted for lack of space. The regularity with which this occurred indicates that for T-beams of the proportions used for these tests the full width of the flange may be considered as fully effective in resisting compression. The calculated compression at loads given in Table 6 was not high, but the compressive stress in the control cylinders at the same unit deformation as that which was developed in the beams at these loads was much higher. This would indicate that the modulus of elasticity for the beams was much lower than that for the cylinders.

The position of the centroid of the compressive stresses was determined from the compressive unit deformations. It was found to be so close to the middle of the depth of the flanges that the use of $d-\frac{t}{2}$ as the value of the moment arm gives an average error for these beams of less than one per cent.

The measured deformations locating the position of the neutral axis are shown in Fig. 11. This figure shows that as closely as the measurements may be used as an indication the sections within the gage length maintained plane sections. Since the entire gage length was within a region of zero shear this experimental verification of the "conservation of plane sections" is not general.

1916-17 TESTS

Purpose and Scope of Tests. This series of tests was more comprehensive than either the 1914 or the 1915 series. Its purpose was to confirm conclusions arrived at on the basis of the previous tests, as to the properties of gypsum, and the behavior of reinforced beams and to extend the investigation farther in every direction.

Shapes and Sizes of Specimens. The specimens tested were of the following shapes and sizes: (a) Cylinders for compression tests. These were 3 in. in diameter by 6 in. long, and 6 in. in diameter by 12 in. long. (b) Bond specimens. These consisted of 8-inch by 8-inch gypsum cylinders having one-half-inch rods 28 in. long embedded axially in the gypsum and extending 20 in. from the center of one of the circular faces. (c) Corrosion specimens consisting of 3-inch by 6-inch cylinders having a one-quarter-inch mild steel bar 5 in. long imbedded throughout its full length in the gypsum. Another form of corrosion specimen consisted of flat pieces of steel 3/16 in. by 1 in. by about 12 in. imbedded in gypsum. These latter tests were started by C. W. Utzman of the United States Gypsum Company.

Reinforced gypsum roof tiles which had been in service in a roof for about four years also were examined and tested to de-

termine the extent of corrosion. (d) Plain beams for determining the modulus of rupture. These beams were 4 by 4 in. in cross section and were 24 in. long. The loads were applied at the one-third points of a 21-inch span. (e) T-beams of two series; those of one series were 8 ft., 6 in. long. The flange was designed to be 1 3/16 in. thick in all cases. The stem width varied from 2 in. to 4 in. and the flange widths from 10 in. to 12 in. All flanges over 10 in. wide were notched down to approximately a 10 in. width in order to permit placing of them between the standards of the testing machine thus giving them in effect a width of 10 in. The details of the reinforcement and of the sizes of the various beams are shown in Table 13.

The beams of the second series were 5 ft. 10 in. long and were tested on a span of 5 ft. 4 in. The stems were all 3 in. wide and the flanges were 10 in. wide. The depth over all was 6 7/16 in. in all cases. The details are given in Table 14.

Molds and Forms. The compression and bond specimens were cast in molds made from steel pipe of the proper diameter and cut to the proper length. The plain beams were cast in steel molds. The T-beams were poured in wooden forms oiled to prevent absorption of the water from the gypsum and warping of the forms.

Special care was used to obtain beams free from twist due to warping of the form lumber. Any twist in a test beam is objectionable because in such a case higher diagonal tension stresses may be caused on one side of the beam than on the other. The lack of uniformity in loads carried by some of the groups of beams may be due to twist which was introduced in spite of the care used to avoid it.

Materials. Fort Dodge second settle gypsum calcined especially for these tests was used for all of the specimens except as indicated in tables and diagrams. The intsructions under which the special calcination was carried out called for the material to be calcined to second settle finishing at a temperature of 400 degrees F., special care to be taken to avoid admixture of foreign material or of material from other batches. The records show that the kettles were dumped at a temperture of 405 degrees F. The material was specified to be reground so that 85 per cent would pass a 100-mesh sieve and at least 99 per cent would pass a 40-mesh sieve. The material was double-sacked to protect it from absorption of moisture and the sacks were tied with wire.

The retarder used is a proprietary material manufactured by the United States Gypsum Company. It was mixed dry with the calcined gypsum in the laboratory where the tests were made. The mixing was done in batches of about 70 lb. of gypsum in a mixer which consisted of a cubical wooden box rotated about a horizontal axis through diagonally opposite corners of the box.

The reinforcing bars varied in size as indicated in Tables 13 and 14. Tests of samples which were representative of beams 15AA1 to 15DG3 indicate a yield-point stress of about 43,000 lb.

per sq. in. High carbon steel was ordered for the remaining beams but its yield-point was not determined.

Consistency. A standard consistency was used for all tests except those in which the water used was one of the variables. To establish a standard consistency a batch was mixed to the consistency which was believed to be the stiffest that could be used in practical work. A reading was then obtained of the diameter of a pat of this material by means of a viscosimeter,[4] designed by G. L. Southard of the United States Gypsum Company and adopted by committee C-11 (on gypsum and gypsum products) of the American Society for Testing Materials. This diameter was taken as the measure of the standard consistency and in subsequent tests the amount of water was used which would give this diameter of 9.7 cm.

Control Specimens. For the purpose of detecting changes in the properties of material from day to day 3 by 6-in. control cylinders were made frequently and tested for strength at an age, usually, of 7 days after storing at 100 degrees F. Some, however, were stored at about 70 degrees F. and tested when dry. These control cylinders all were made at standard consistency and in most cases 0.1 per cent retarder was used. Some control specimens, however, were made from the unretarded material. Table 1 gives the results of the tests of the control cylinders.

Making of Small Specimens. At frequent intervals, or just before making specimens, a determination was made of the amount of water required for the standard consistency. The required amount of water was measured out, the gypsum was weighed out and poured slowly into the water. The mixture was allowed to soak about two minutes before any stirring was done. By vigorous stirring (usually about 30 to 60 sec.) the mixture was then brought to an even consistency and poured into the mold. Only enough material for one specimen was mixed in each batch. Usually an allowance of 10 per cent was made for waste in the form of gypsum which sticks to the mixing vessel and can not be poured out into the mold. The mixing vessels and molds were kept free from set gypsum. It is recognized that this does not correspond to the conditions of practice but it was believed to be necessary to eliminate the irregularity which would be brought about by the use of dirty vessels, since this irregularity would be likely to obscure the trend of the results. All specimens were weighed at the time of the removal of the forms, which was usually about one hour after pouring the specimens.

Storage. In this paper two methods of storage are referred to —kiln-storage and so called air-storage. The kiln used was 8 ft.

4. This viscosimeter consists essentially of a small cylindrical cup whose bottom is a piston. With the piston set at a fixed position the cup is filled with the gypsum mixture and the piston is moved upward at a predetermined rate until it is even with the top of the cup. This causes the gypsum mixture to flow out upon a plane horizontal surface which is exactly flush with the top of the cup. The diameter of the pat of gypsum so formed is taken as a measure of the consistency of the mixture. For fuller description see Proc. Am. Soc. Testing Materials, 1919 Report, Committee C-11.

square in plan and 6 ft. high. It was provided with means for controlling temperature and humidity. The temperature at various portions of the kiln under working conditions was found to vary by not more than one or two degrees throughout the kiln. Storage in the open in the laboratory is termed air-storage. The temperature of the laboraotry would ordinarily be about 70 degrees.

Methods of Testing. For the most part the compression and flexure tests were made in a small testing machine designed by the writer for the United States Gypsum Company in which the load was applied by means of a jack and measured by means of the deflection of a calibrated steel spring, sensitive and accurate to about 50 lb. The bearing surfaces of the compression specimens were formed at the time of making the specimens, so that capping of specimens just previous to testing was not necessary.

The bond specimens were tested in a 40,000 lb. Riehle Testing Machine at Lewis Institute as described on page 402.

The corrosion specimens were tested[5] by weighing the ¼-inch bars 5 in. long after having cleaned them of mill scale by immersion in hydrochloric acid, washing with water and drying with alcohol. After imbedding the bar in the gypsum cylinder and allowing the specimen to stand the required length of time the specimen was broken open and the bar was removed, cleaned of fragments of gypsum and immersed for one hr. and 15 min. in a 10 per cent solution of fresh ammonium citrate at room temperature to clean the bar of oxide of iron. The bar was then weighed again and the difference between this weight and its original weight was considered to be the amount of corrosion. An uncorroded bar of the same size thoroughly cleaned of mill scale showed a loss of only 0.0046 gm., or 0.00018 gm. per sq. cm. due to immersion in the solution of ammonium citrate for one hr. and 15 min. This is less than one per cent of the amount of corrosion found for the bars imbedded in the gypsum having no lime and may be taken to indicate that the error in this method of measuring corrosion is slight. The method of making other corrosion tests is described in connection with the discussion of the results:

Percentage Variation from Average. The specimens were tested in groups of five of a kind. The maximum variation of any one specimen from the average of the five seldom exceeded 15 per cent of the average strength for the five specimens. The average variation from the average strength was about 5 per cent.

Weight of Hydrated Gypsum When Dry. The percentage of water used in mixing the calcined gypsum is shown in Fig. 12 to have considerable effect on the weight of the hydrated gypsum per cubic foot after drying out and on the amount of calcined gypsum required per cubic foot of the hydrated gypsum. Fig. 12 shows the

5. The details of the method of measuring loss by corrosion were learned by correspondence with Clarence W. Noble, Toronto, Canada, who published results of similar tests in a pamphlet "Why Copper Alloy." The U. S. Bureau of Standards also was consulted on this matter.

weights of dry hydrated gypsum per cubic foot for the various percentages of water used. The weight of the mixture of gypsum which seemed most suitable for structural purposes was about 80 lb. per cu. ft. slightly more than one-half that of ordinary concrete.

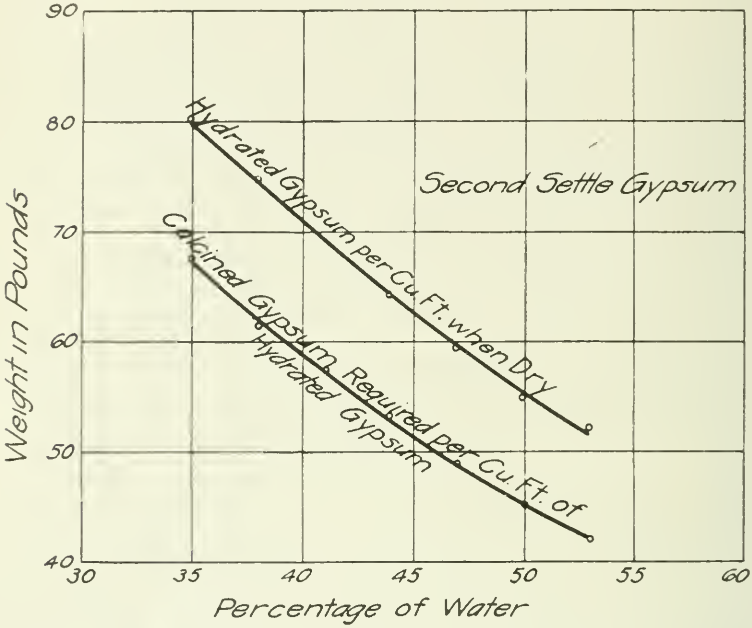


Fig. 12. Relation Between Percentage of Water Used, and Weight of Hydrated Gypsum

Within the range of percentages of water used, the following equations may be used for estimating weights of materials and structure:

$$w_c = 116 - 1.40p_w \quad \ldots\ldots\ldots\ldots\ldots\ldots (1.)$$
$$w_a = 135 - .87p_w \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.)$$
$$w_d = 138 - 1.67p_w \quad \ldots\ldots\ldots\ldots\ldots\ldots (3.)$$

In these equations—

w_c = weight of calcined gypsum required per cubic foot of hydrated gypsum.

w_a = weight per cubic foot of hydrated gypsum at time of set before any drying has taken place.

w_d = weight of dry hydrated gypsum per cubic foot.

p_w = water used in mixing, stated in percentage of total weight of water and gypsum.

These are equations of straight lines and it is apparent from observation that the curves representing these weights are not straight lines. Parabolas could be fitted to the points with considerably greater exactness but the straight lines pro posed will give

the weights correctly within about one per cent for percentages of water between 35 and 55. This is as great accuracy as can be used in estimating quantities of material and weight of structures. As p_w approaches zero w_a and w_d from equations (2) and (3) should approach a common value. The values 135 and 138 are close enough together to indicate that by using equations of curves instead of straight lines this condition could be realized. Comparing equations (1) and (3) it is found that the weight of the calcined gypsum used was about five-sixths of the weight of the resulting hydrated gypsum when dry.

It was found in the 1914 tests that weights for first settle gypsum were very closely the same as the weights shown in Fig. 12 which are for second settle gypsum. Apparently the same equations may be used for estimating weights regardless of whether first settle or second settle gypsum be used.

Time Required for Drying. Fig. 13 shows the rate of drying of 3x6-in. cylinders and 6x12-in. cylinders both at 100° F. and at about 70°. The storage conditions were such that the specimens were not struck by air currents. The 6x12-in. cylinders are from the 1914 tests and all others are from the 1916-17 tests. For a given size of specimen and for given storage conditions the evaporation

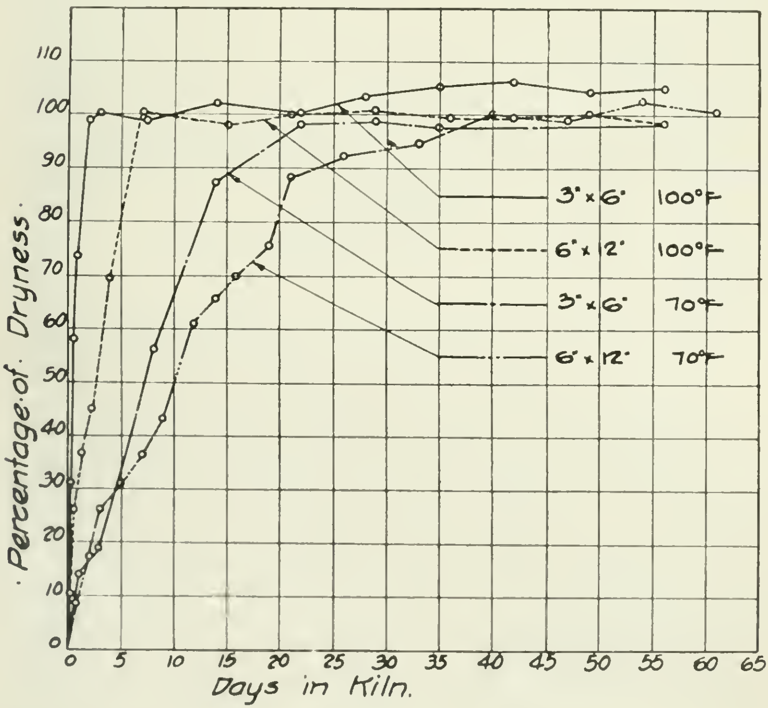


Fig. 13. Rate of Drying of Gypsum Specimens

of the excess water progressed approximately in direct proportion to the lapse of time. For the specimens dried at 100° F. this held true up to the time that the specimen was 100 per cent dry, that is, up to the time that all the water in excess of that required for crystallization had been evaporated. At the point of complete dryness there was a sharp change in direction of the evaporation curve. The shorter the time of drying the sharper is this change in direction.

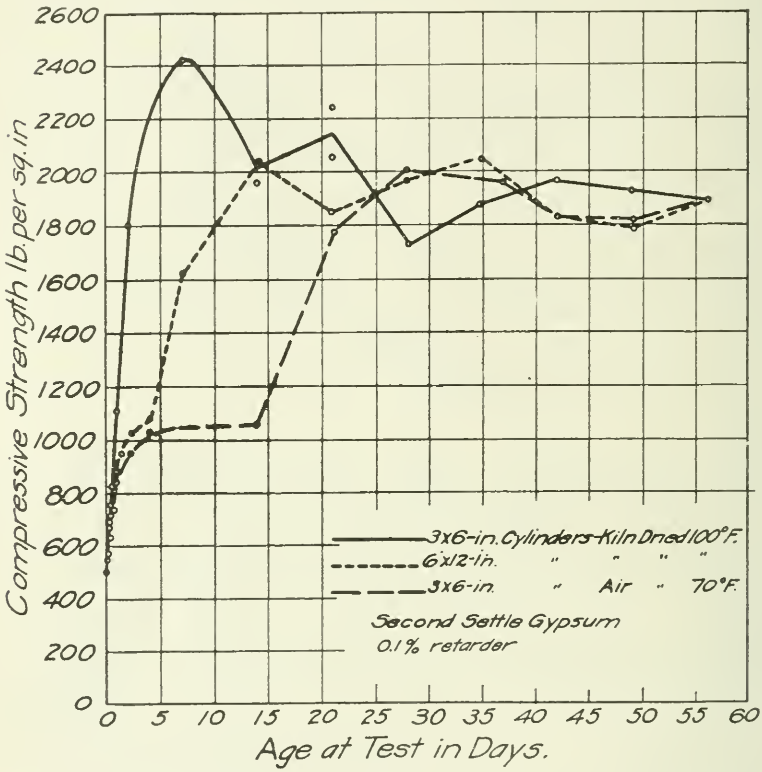


Fig. 14. Effect of Age on Compressive Strength of Gypsum

For the specimens dried at 70° the change in direction of the evaporation curve was less sharp and occurred at about 88 per cent dryness.

The time required for complete drying was much less for the small specimens than for the larger ones and much less for the specimens dried at 100° F. than for those dried at room temperature (about 70° F.).

Effect of Drying Out on Compressive Strength of Gypsum. The results of this series of tests indicate a progressive increase in strength up to the time that all the water in excess of that which

is required for complete hydration has been evaporated. The highest value reached by any group in this series was about 2400 lb. per sq. in. at an age of about 7 days. (See Fig. 14.) Numerous other tests verify the approximate correctness of this maximum value. The strengths of the same specimens have been plotted in Fig. 15 against the percentage of dryness. The computation of the percentage of dryness is based upon the assumption that all the

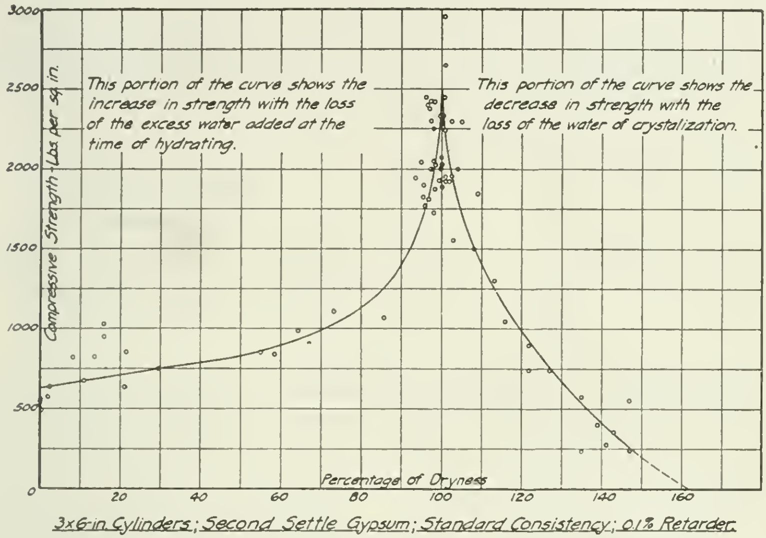


Fig. 15. Relation Between Percentage of Dryness and Compressive Strength of Gypsum

gypsum is hydrated to $CaSO_4\ 2H_2O$. On this basis a dryness of 100 per cent corresponds to the evaporation of all the water in excess of that required for complete crystallization. The occurrence of a dryness greater than 100 per cent corresponds to the evaporation of some of the water of crystallization. The highest strength appears to occur where specimens were 100 per cent dry. The correct determination of the percentage of dryness is dependent upon a knowledge of the percentage of moisture and the percentage of foreign matter in the calcined gypsum and since these values were known only approximately there is some uncertainty as to whether any of the water of crystallization was evaporated in any case where the drying temperature was 100 degrees F.

The highest strength for the 100-degree drying temperature was greater than that for the 70-degree. The advantage of drying at 100° F. was only temporary, however, since with a continuation of this temperature the strength fell off from about 2400 lb. per sq. in. to about 1900 lb. per sq. in. The same falling off of strength occurred for specimens which were removed from the 100° temperature at an age of about 10 days and stored at about 70° for 3 months.

The indications are that this lot of second settle Fort Dodge gypsum when molded at standard consistency and stored at a temperature not higher than 100° F. would attain a permanent strength, when kept dry, of about 1900 to 2000 lb. per sq. in. when tested in the form of a cylinder whose diameter equals one-half its height.

Effect of Percentage of Gaging Water on Compressive Strength. The results of these tests are given in Fig. 2 and conform in a general way to those of the 1914 tests in that the larger percentages of water greatly decreased the strength of the specimen. The rapidity with which the strength decreased with the increase in the percentage of gaging water emphasizes the importance of keeping the percentage of gaging water as low as possible in all cases in which strength is an important consideration.

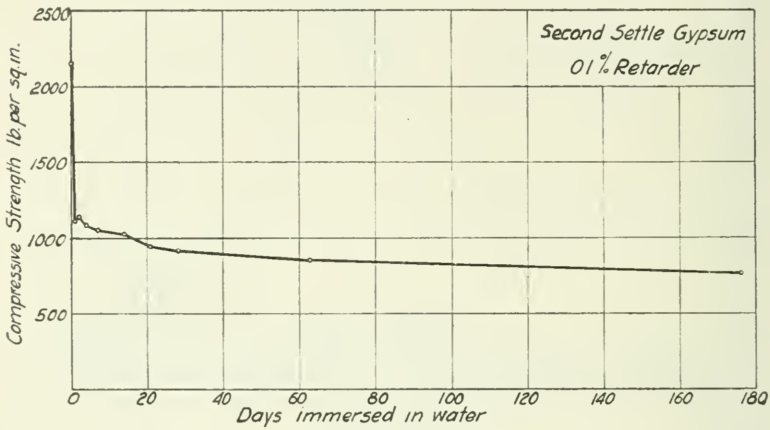


Fig. 16. Effect of Soaking in Water on Compressive Strength of Gypsum

The lower curve in this figure (for first settle gypsum) is from the 1914 tests. It should be noted that the difference in strength for the two curves is probably due largely to the difference in dryness and only partly to the fact that one curve is for first settle and the other for second settle gypsum.

This is brought out by the fact that first settle gypsum with 0.15 per cent retarder and 35 per cent water tested when the specimen was thoroughly dry (182 days old) developed a strength of 2087 lb. per sq. in. while a specimen of the same kind tested at an earlier age showed a strength of only 869 lb. per sq. in. This is shown in Table 1.

It is of importance that the difference in size of cylinders for the lower curve of Fig. 2 had little effect on the strength of the cylinders. This gives confidence in comparisons of strengths of cylinders of different sizes, so long as the ratio of height of cylinder to its diameter is the same.

Effect of Continued Soaking on Compressive Strength. Specimens thoroughly dried were exposed to moist air and it was found

that the absorption of 0.3 per cent of moisture (percentage of weight of dry specimen) from the air in one hour reduced the strength from 1730 to 1220 lb. per sq. in.

Other specimens were then immersed in water and the strength fell off in a very short time[6] to about 50 per cent of the original strength as shown in Fig. 16. The strength then decreased very slowly until at an age of 176 days the strength was still about 40 per cent of the original strength for the dry specimens. These results confirm the observations in a previous series of tests.

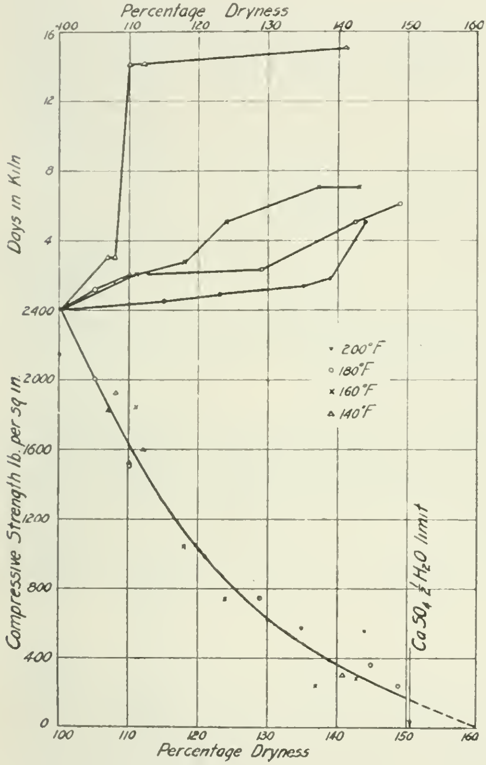


Fig. 17. Effect of Variation in Storage Temperature on Compressive Strength and Dryness of Gypsum

Effect of Variation in Storage Temperature on Compressive Strength. Cylinders of second settle gypsum, 3x6 in., mixed to normal consistency were stored at 100 degrees F. and allowed to become 100 per cent dry. They were then removed from the kiln and allowed to stand through the summer (1916) in the laboratory at room temperature. They were stored again in the kiln at temperatures of 140 degrees, 160 degrees, 180 degrees and 200 degrees F. respectively and weighings were made at intervals to determine the loss of water of crystallization. They were tested for compressive strength in groups of five at various percentages of dryness. The program for each temperature as planned was to remove and test one group of five specimens when each of the following percentages of water had been evaporated; 20, 40, 60, 80 and 100 per cent of the total water, which finally could be driven off at the temperature under consideration. An interruption of the program prevented the completion of the tests

6. These specimens were left in water 24 hours before testing and it is not known how much less exposure than this would have caused the same loss in strength. Indications from a previous series of tests are that the loss probably occurred in much less than 24 hours.

of specimens stored at 140 degrees and prevented entirely the securing of information on the effect to storing at 120 degrees. The percentage of dryness for the various times and temperatures has been shown in Fig. 17. This shows that for the specimens stored at 200 degrees the drying out was very rapid, and that for those stored at 140 degrees it was slow up to 14 days. After 14 days a sudden increase in the rate of drying appears to have occurred. The percentages of dryness shown for specimens dried 14 days at 140 degrees look doubtful when considered by themselves, but two points (each one the average result of weights of five specimens) confirm each the correctness of the other. The strengths, also, of these specimens and of those dried 15 days at 140 degrees correspond so closely to the strength expected for their respective percentages of dryness as to give a further check on the correctness of the determination of percentages of dryness.

The conditions are such as to indicate a lack of uniformity in temperature at all parts of the kiln, although a thorough trial of the kiln previous to starting the tests had shown a variation of not more than two degrees F. in different parts of the kiln. Apparently the lowest temperature which if long continued will cause a loss of water of crystallization and below which no such loss will occur has not been determined.

The lower part of Fig. 17, is of the same nature as the right hand portion of Fig. 15. This brings out the fact that the loss in strength is dependent entirely upon the amount of loss of water of crystallization and not at all upon the time required to produce that loss or the storage temperature used. Although the loss of water from the specimens stored at 140 degrees was very slow it is important to note that the slight loss of water found after storing two weeks at this temperature caused a loss of 25 to 30 per cent in compressive strength.

Assuming (as an average which will fit the case quite closely) that the moisture and the impurities found in this calcined gypsum are each 5 per cent of the weight of the calcined gypsum and that this wet specimen was 38 per cent water by weight, it is found that the gypsum has been reduced to $CaSO_4\ \frac{1}{2}H_2O$ (plus impurities) when it is 151 per cent dry and to $CaSO_4$ when it is 165 per cent dry.

Effect of Age on Calcined Gypsum. The control cylinders used for the purpose of detecting any changes which might occur in the properties of the special material from which the test specimens were being made give some information on the effect of age on the properties of second settle gypsum. This lot of gypsum was calcined on March 31, 1916, and the first specimen was made on April 29, 1916. Table 7 gives a record of all the control specimens made for the above purpose. The data of this table do not indicate that with increasing age there was any material change in the strength. However, with the slight increase in the amount of moisture in the calcined gypsum there was a steady decrease in the

Table 7. Control Specimens for 1916-17 Tests

Specimen No.	Percentage Gaging Water	Percentage Moisture	Consistency Reading	Weight of 3 specimens, gm. When Made	Weight of 3 specimens, gm. At Test	Percentage Dryness	Compressive Strength, lb. per sq. in.	Variation from Average Maximum	Variation from Average Average
Dried in Kiln at 100° F. Age at test, 7 days.									
U-4-29-1 to 3	38	....	9.6	3,398	2,535	102.7	2,400	1.4	0.9
R-4-29-1 to 3	38	....	9.6	3,385	2,515	104.0	1,920	12.4	8.2
U-5- 2-4 to 6	38	....	9.7	3,450	2,600	99.5	2,680	5.4	3.5
R-5- 2-4 to 6	38	....	9.7	3,425	2,560	101.5	2,340	8.3	5.5
U-5- 5-7 to 9	37	....	9.7	3,485	2,655	99.5	2,730	7.9	5.3
R-5- 5-7 to 9	37	....	9.7	3,390	2,579	99.5	2,440	13.5	9.1
R-5- 8-10 to 12	37	4.32	9.7	3,400	2,595	98.8	2,380	20.6	13.7
R-5- 8-13 to 15	37	4.22	9.7	3,390	2,550	103.5	2,240	13.7	9.1
R-5- 8-16 to 18	38	4.22	11.8	3,340	2,190	102.7	2,450	6.6	4.5
R-5-15-19 to 21	37	4.98	9.7	3,365	2,535	103.2	2,300	12.4	8.2
R-5-19-22 to 24	37	3.47	9.7	3,340	2,500	104.5	2,310	3.6	2.4
R-5-31-25 to 27	37	4.60	9.7	3,360	2,530	103.2	1,930	7.9	5.3
R-6- 7-28 to 30	37	4.73	9.7	3,365	2,540	102.3	2,070	2.9	1.5
R-6-10-31 to 33	37	4.35	9.7	3,440	2,600	102.2	2,340	2.2	1.4
R-6-16-34 to 36	36	4.68	9.7	3,470	2,655	102.5	2,020	7.3	4.9
R-6-27-37 to 39	36	5.07	9.7	3,475	2,710	94.2	1,940	7.9	3.9
R-6-29-40 to 42	36	4.91	9.7	3,420	2,640	99.5	2,400	8.5	5.6
Dried in Laboratory at room temperature. Age at test, 30 days.									
R-7-10-43 to 45	35	4.84	9.7	3,445	2,650	105.5	2,020	2.7	1.9
R-9- 1-46 to 48	34	5.24	9.7	3,305	2,625	99.8	2,460	5.9	3.9
R-9- 8-49 to 51	34	5.20	9.7	3,480	2,695	109.0	2,300	2.3	1.5
R-9-25-52 to 54	34	5.20	9.7	3,445	2,750	101.7	2,000	7.2	4.8
R-10-6-55 to 57	33	4.7	9.7	3,555	2,825	104.0	2,950	3.3	2.2
R-10-6-58 to 60	33	4.7	9.7	3,490	2,770	104.7	2,650	8.3	5.5

General Notes.

For all specimens: 3x6-in. cylinders; Ft. Dodge second settle specially calcined gypsum; each strength average for 3 specimens.

In the numbering of the specimens the initial "R" indicates a specimen having 0.1 per cent retarder and "U" indicates a specimen having no retarder. The second and third numbers indicate the month and day on which the specimens were made, and the third number indicates the serial number of the specimen. For example R-5-31-27 was a retarded specimen made on May 31 and having serial number 27. Consistency readings are diameters of pats in centimeter.

amount of water required to give the standard consistency. This is shown in Fig. 18 for second settle gypsum. Unfortunately it was not possible to make the storage conditions the same for all the control specimens and this must be taken into consideration in judging of the results.

The earlier specimens of the series were stored in the kiln at a temperature of 100 degrees F., but it was necessary to store the control cylinders made in August and September, 1916, in the laboratory at room temperatures. It should be noted, too, that some of the specimens made at about this time were nearly a month old, while those made earlier were all tested at seven days age.

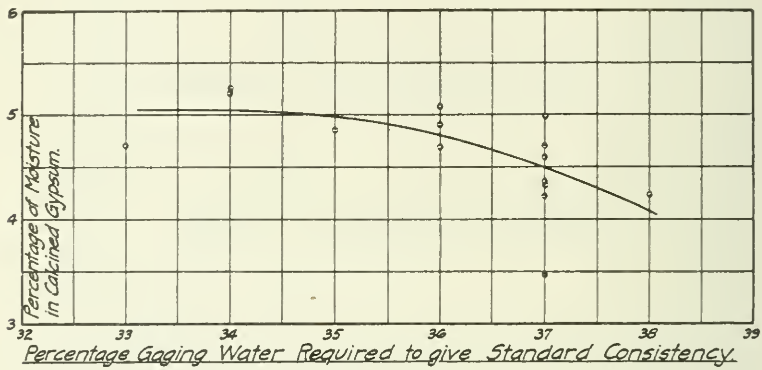


Fig. 18. Relation Between Percentage of Moisture and Water-carrying Capacity of Gypsum

Effect of Hydrated Lime on Compressive Strength. In Figs. 19, 20 and 23 the hydrated lime is expressed as a percentage of the total weight of lime and calcined gypsum. Fig. 19 shows a steady decrease in strength with increased percentage of lime until the strength in specimens having 10 per cent of lime was only 70 per cent of the strength of those with no lime. All the specimens had 0.1 per cent retarder but those having no lime showed a higher strength than was found for most specimens of other series having 0.1 per cent retarder and no lime. It may be that this excess is due to the fact that these specimens were tested at four days age, at which time the curve in Fig. 15 indicates an abnormal strength for specimens dried at a temperature of 100 degrees F.

Bond Strength in Pull-out Tests: Effect of Adding Hydrated Lime. The specimens tested when wet show little effect of the addition of lime and show a very low bond strength. Those tested when 75 per cent dry indicate a decrease in bond strength with addition of lime up to 2 per cent of the total weight of the lime and calcined gypsum, but a further addition of lime had little effect on the bond strength. The specimens tested dry show a very marked decrease in strength with the increase of the percentage of lime up to 4

per cent. Beyond this the additional lime had little effect on the bond strength. The lowest bond strengths for the dry specimens are creditable and the highest are unexpectedly high. An interesting feature of these tests is the regularity and consistency of the variation in bond strength.

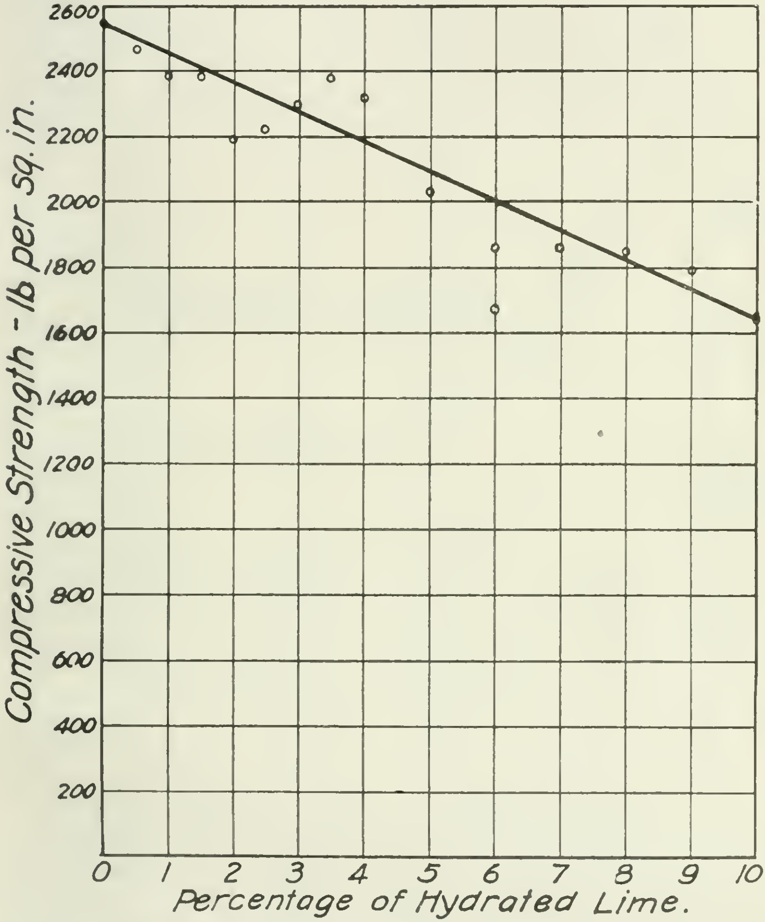


Fig. 19. Effect of Hydrated Lime on Compressive Strength of Second Settle Gypsum Dried at 100 Degrees F

The similarity of the curves of bond strength, (Fig. 20) and of amount of corrosion, (Fig. 23) indicates that the decrease in bond strength with increase in lime may be due to the reduction of the initial corrosion with the use of lime. In Fig. 21 the bond strength has been plotted as ordinates with the amount of corrosion as abscissas and it appears that the increase in bond strength is almost proportional to the increase in the amount of corrosion.

That the reduction in bond strength with increased lime content is due to the corresponding reduction in corrosion is further indicated by the fact that for the earlier tests at one day and 22 days' age, before the corrosion had had full opportunity to form and to dry, there is little effect of lime on bond strength.

Bond Strength in Pull-out Tests: Effect of Variation in Amount of Gaging Water. Fig. 22 shows that with the drier mixes

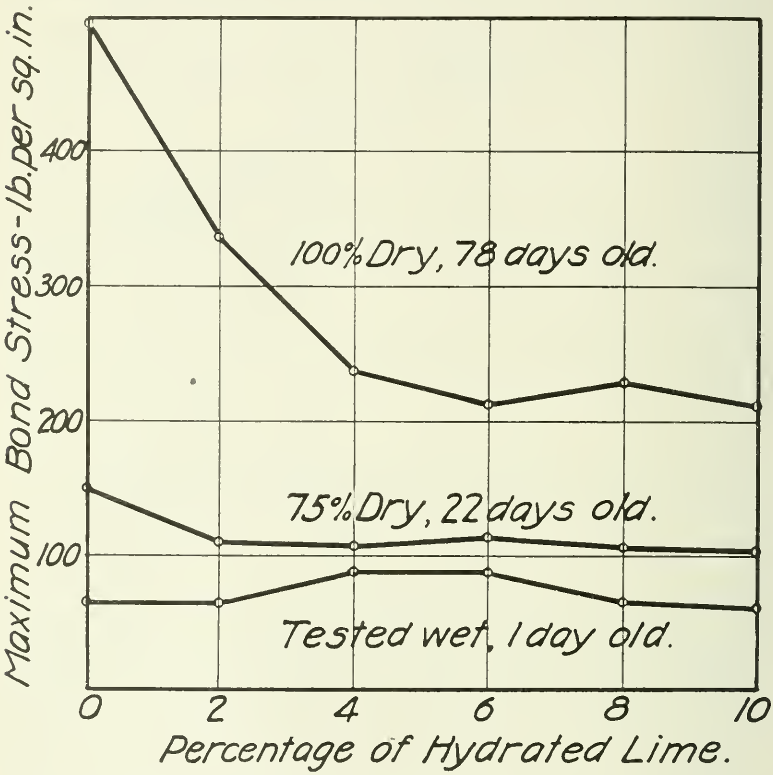


Fig. 20. Effect of Hydranted Lime on Bond Strength of Second Settle Gypsum, 0.1 Per Cent Retarder, Standard Consistency, Dried at 70 Degrees F

it is possible to obtain a high bond strength. The fact that the specimens were thoroughly dry probably accounts for the higher bond stresses than those found in previous tests. It is believed that the mixture having 36 per cent of water had about the consistency which could be used in practice, and that the one having 34 per cent would be somewhat too stiff for practical use, though this question is still somewhat uncertain.

Effect of Hydrated Lime on Corrosion of Reinforcing Bars. In these tests the loss of weight by corrosion was less for steel specimens imbedded in gypsum to which hydrated lime had been added

than for specimens imbedded in gypsum with no addition of lime. There seems to be no pronounced advantage from the standpoint of its effect on corrosion, in the addition of more than 4 per cent of lime. This result is shown in Fig. 23. The actual amount of corrosion even with specimens having no lime in their makeup is not enough to be of importance in itself, but if the rate of corrosion found at 71 days were to continue undiminished it would be an important consideration. The diagram shows that there was no appreciable loss between the ages of 81 days and 243 days and indicates that corrosion does not progress after the excess water has been lost by drying out of the specimens.

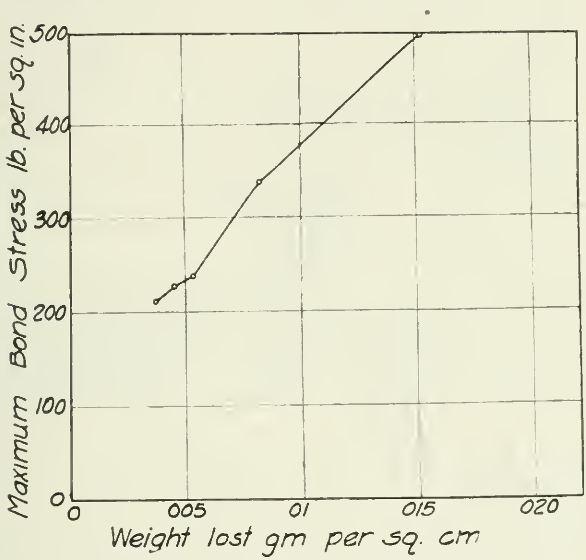


Fig. 21. Relation between Bond Strength and Amount of Corrosion

Corrosion in Reinforcement of Roof Tile. To determine how much the strength of reinforced roofing tile in actual service is affected by corrosion of the reinforcement a number of tiles 12 in. wide and 30 in. long were removed from the roof of the United States Gypsum Company's mill at Oakfield, N. Y. Six of them were selected in a portion or portions of the building where there was good protection from exposure to moisture. Six more were taken from portions of the roof where serious leaks had developed and the tiles at the time of test were decidedly wet. Two of these tiles were tested at Lewis Institute, Chicago, by applying a concentrated load at the center of the span. One of the tests was made on a dry tile and the other on a wet one.

In the test of the first tile the span used was 28 in. center to center of supports. A plastic gypsum bed was used to give

uniformity of bearing at the reaction and at the load point. The maximum concentrated load carried was 1500 lb. or the equivalent of a uniform load of 1250 lb. per sq. ft. The failure seemed to be due to high tension in the reinforcement though some diagonal tension cracks developed. The computed stress in the reinforcement was 67,000 lb. per sq. in.

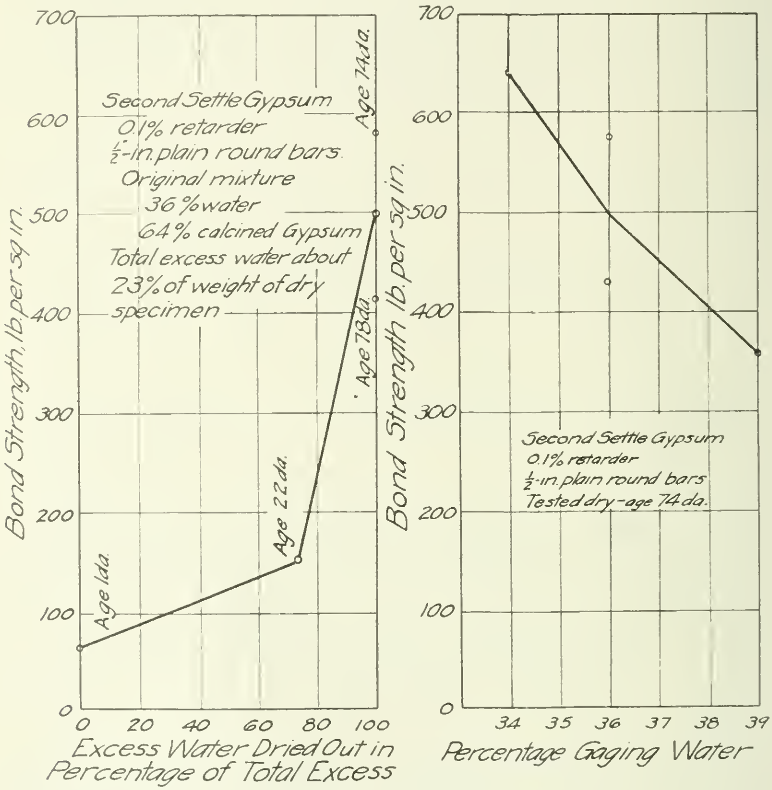


Fig. 22. Effect of Amount of Gaging Water on Bond Strength of Gypsum

The second tile tested was one which had been taken from a leaky place in the roof. The material in this tile was very wet even at the time of test and as this was several weeks after their removal from the roof it seems likely that they had been wet much of the time when in service. The end of the tile was so badly damaged that it did not seem that a good bearing could be obtained at the end of the tile and a span of about 24 in. was used instead of the full span of 28 in.

The maximum total load applied at the center of the 24-in. span was 600 lb. and the failure seemed to be due to tension in the

reinforcement. The total concentrated load which on a span of 30 in. would have produced the same bending moment as the load which was applied amounts to 500 lb. That is, this tile would have had a factor of safety of about three when supporting at the center a man of ordinary weight. The equivalent uniform load per square foot would be about 400 lb.

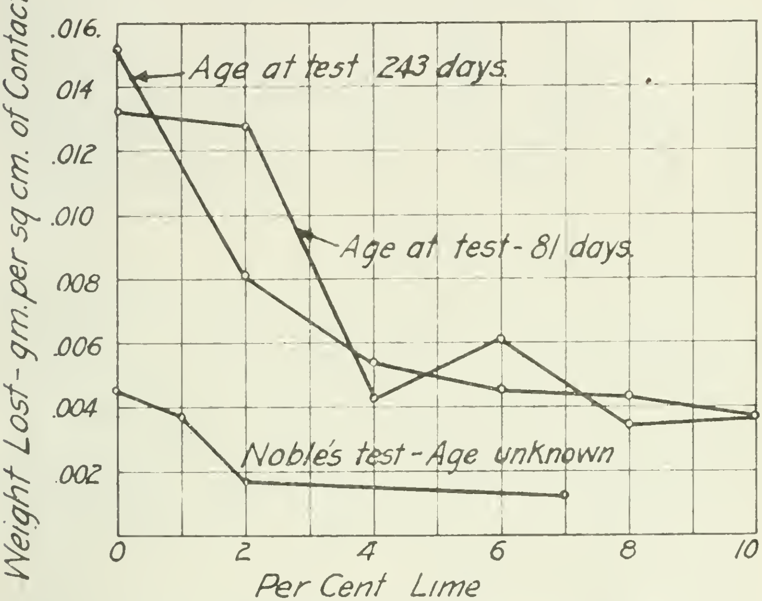


Fig. 23. Effect of Hydrated Lime on Corrosion

After the load tests had been completed examination was made of the tile and it was found that for the first test the reinforcement had slipped at one end about 1/8 in. The reinforcement of this first tile was slightly rusted on the surface, but did not give the appearance of being deeply corroded. Tension tests were made on this wire and in these tests (see Table 8) a tensile strength of 62,000 lb.

Table 8. Tensile Strength of Wire from Roof Tile

Ref. No.	Condition	Area sq. in.	Tensile Stress, lb. per sq. in. Yield Point	Maximum Load
1	Corroded	.00500	51,000	62,000
2	Corroded	.00175	67,100	68,500
3	Corroded	.00168	57,600	63,000
4	Corroded	.00178	61,750	68,000
		Average	60,190	65,375
5	Uncorroded	.00192	57,000	67,000
6	Uncorroded	.00192	62,000	73,200
7	Uncorroded	.00174	73,800	83,500
		Average	64,266	74,566

per sq. in was developed. In the tile which was wet when tested serious corrosion had taken place. In the process of removing the reinforcement from this tile the reinforcement was broken in many places. In fact it seemed that in many places it may have been severed by the corrosion.

The writer is informed that the tiles had been in place in the Oakfield Mill since 1912, or more than four years, that the reinforcement used was ungalvanized and that the conditions which caused the corrosion reported were artificially produced for the purpose of making the most severe corrosion test possible. The high strength shown by the tile tested when dry and by the reinforcement removed from it, when considered in connection with the serious degree of corrosion found in the tile which was wet when tested, go to indicate that the active agent in causing corrosion of reinforcement imbedded in gypsum is the absorbed water which is present and not the gypsum itself.

Since the completion of the investigation on which the results reported in the preceding paragraphs are based, evidence has been secured indicating that for tiles exposed to the action of sulphur fumes the seriousness of corrosion depends largely upon the proximity of the reinforcing metal to the surface of the gypsum. It is not improbable that this may be a factor of some importance in cases where corrosion is brought about by other causes.

An examination was made of the condition of the reinforcing wires in roof tile taken from an exposed position in the C. M. & St. P. Ry. roundhouse at McGregor, Iowa. Representatives of the C. M. & St. P. Ry. were present at the examination of the specimens selected for this purpose.

The following quotations regarding this inspection are taken from the report by N. H. LaFountain, general supervisor of buildings for the C. M. & St. P. Ry., to the chief engineer, C. F. Loweth:

"Six slabs altogether were removed, taken out from over one of the stalls most used, at different points in the roof. Our examination developed the fact that the wire reinforcing in the bars was put in without much regard for uniformity. The bars in some of the slabs were from ½ in. to ¼ in. from the face of the slab, while others were so close to the surface that there was left a mere film of gypsum over the wires. In that case, the exhaust from the engine apparently shattered the film of gypsum, and left the wires exposed without protection. In that case, the wires had started to rust, and in several spots the section of the wire had been considerably reduced by corrosion.

"Where the reinforcing wires had been properly put in, there was no indication whatever of rust or disintegration. In fact, they appeared to be as bright and sound as when they were put in The gases seem to have no action whatever on the gypsum, and do not seem to penetrate into it."

Additional Corrosion Tests. About 1914 a series of corrosion tests was started under the direction of Mr. C. W. Utzman of the

Table 10. Physical and Chemical Analyses of Gypsum from Several Mills

	Alabaster Mill	Blue Rapids Mill	Ft. Dodge Mill	Oakfield Mill	Southard Mill
Physical—					
Percentage of Gaging Water Required for Standard Consistency	37.0	38.0	39.0	37.0	37.0
Dry Bulk—c.c. per gm.........	.72	.84	.88	.76	.80
Passing 40 mesh sieve........	99.8	99.6	99.6	99.7	99.4
Passing 100 mesh sieve........	95.2	95.0	84.6	95.2	92.2
Chemical—					
Moisture (Combined Water)....	5.4	5.95	5.83	5.46	6.04
$CaSO_4$ { CaO	36.94	38.03	37.04	35.97	36.79
$CaSO_4$ { SO_3	52.68	54.22	52.84	51.29	52.47
Insoluble (Silica and Insoluble)	2.10	1.32	3.12	1.32	.92
$Fe_2O_3 + Al_2O_3$ (Iron and Alumina)	.40	.16	.40	.14	.08
$CaCO_3$ { CaO	1.59	.44	.67	2.36	1.56
$CaCO_3$ { CO_2	1.25	.35	.52	1.85	1.22
$MgCO_3$ { MgO	.05	...	Trace	.56	.69
$MgCO_3$ { CO_2	.05	...	...	.62	.75
NaCl	.03	.03	.07	.07	.06
Total	100.51	100.50	100.51	99.64	100.58

Compressive Strength of Second Settle Gypsum from Various Mills. For this series of tests samples of second settle gypsum, such as is put on the market by the United States Gypsum Company, were obtained from the company's mills at Fort Dodge, Ia.; Blue Rapids, Kan.; Oakfield, N. Y.; Southard, Okla., and Alabaster, Mich. Three by six-in. cylinders having 0.1 per cent retarder and mixed at standard consistency were stored at 100

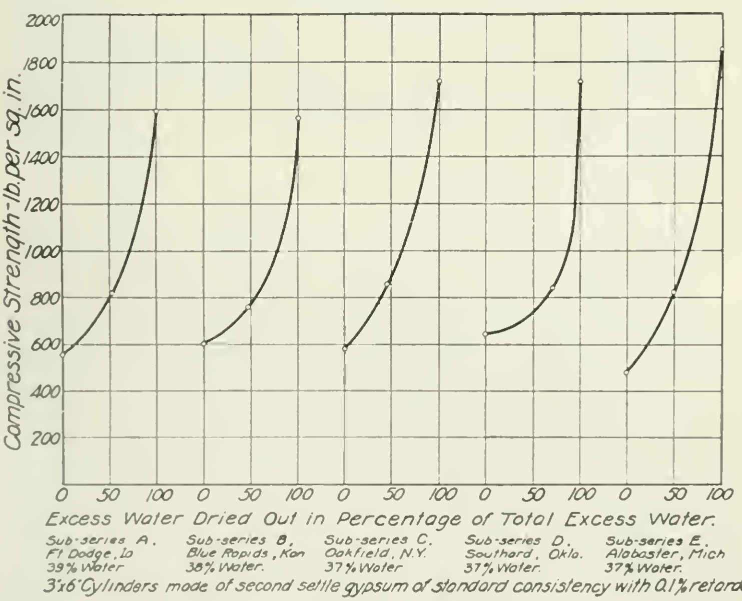


Fig. 24. Compressive Strength of Second Settle Gypsum from Various Mills of the United States Gypsum Company

United States Gypsum Company. For these tests flat pieces of steel $\frac{3}{16}$ in. thick, 1 in. wide, and about 12 in. long were imbedded in prisms of gypsum. These specimens were exposed to the action of the out-door air with whatever moisture was present. They were protected from direct contact with water during rain storms, but at intervals of 13 weeks certain of the specimens were soaked in water for about one-half hour.

At intervals of 13 weeks after the making of a specimen a length of one inch of the prism of gypsum was cut away and an examination was made to determine visually the amount of corrosion due to contact with the gypsum. The uncovered portion of the steel was then varnished to prevent further corrosion, and the test was continued as before. Up to the time of preparing this report examination had been made of eight consecutive inches of the bar for an exposure of 104 weeks for the longest and 13 weeks for the shortest test. To determine the maximum amount of area lost by corrosion the specimen showing the most extreme corrosion of any was selected and the varnish removed from the entire 8-in. length of uncovered steel. This specimen was one which had been soaked in water at intervals of 13 weeks. The rust was removed by means of ammonium citrate and micrometer measurements (estimated to the nearest 0.0001 in.) of the thickness of the plate were made at distances from the end corresponding to the various lengths of exposure. These values are shown in Table 9.

Table 9. Corrosion of Plate Embedded in Gypsum

Exposure, Weeks	Thickness, Inches
13	.1840
26	.1840
39	.1841
52	.1838
65	.1835
78	.1838
91	.1839
104	.1838

The indication from this table is that the progressive loss due to corrosion was very small. In fact the variations in measurement are not more than frequently may be found at different points on a bar which had not been subjected to external action of any kind and may represent merely the unevenness formed in the rolling process.

The specimen selected for the measurements was made of gypsum from the Grand Rapids mill. This series of tests includes specimens made using gypsum from other mills of the United States Gypsum Company.

For most of the specimens so little corrosion had taken place, and the process of removing the varnish and the slight amount of rust present was so tedious, that no other micrometer measurements were taken.

degrees F for four days before testing. The chemical and physical analyses and the results of the tests are shown in Table 10 and Fig. 24. The results show a satisfactory uniformity for the various mills.

Effect of Retarder on Compressive Strength of Hydrated Gypsum. For the specimens stored at a temperature of 100 degrees F it was found that with any amount of retarder which might be used in the calcined gypsum a loss in compressive strength occurred.

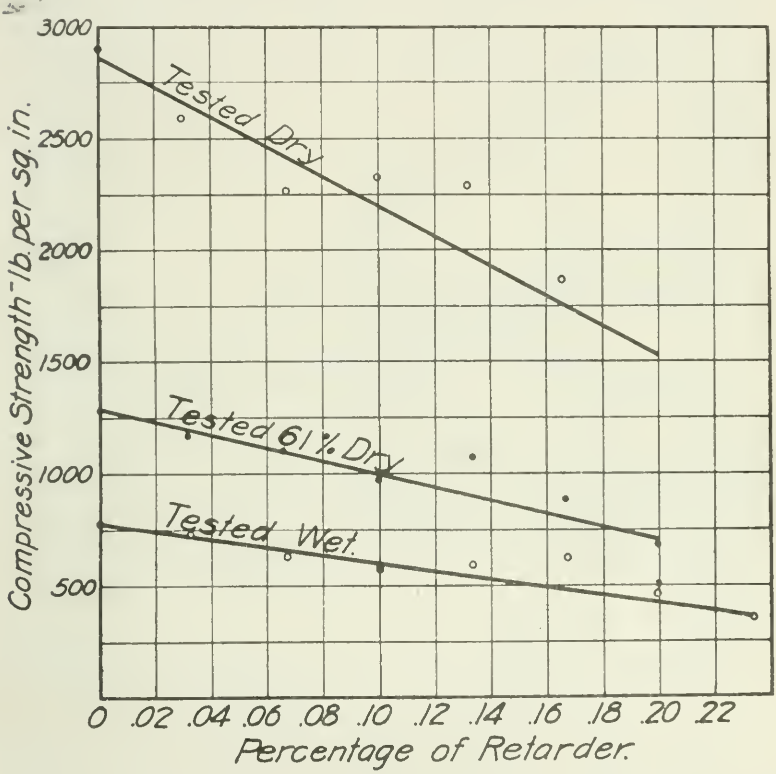


Fig. 25. Effect of Amount of Retarder on Compressive Strength of Second Settle Gypsum Dried at 100 Degrees F

This is shown in Fig. 25. This was unexpected since the 1914 tests had indicated that for amounts of retarder up to 0.1 per cent, an increase in strength might be expected. To determine the reason for the inconsistency the tests were repeated under a variety of conditions. This brought out the fact that when the conditions of the 1914 tests were duplicated the results of those tests were confirmed, but that for any other conditions tried, the conclusions from those tests do not apply. It was found that when first settle gypsum was stored at ordinary room temperatures of about 65 to 75 degrees F

the addition of 0.1 per cent retarder caused a material increase in the strength but that a further addition of retarder caused a decrease in the strength. This agrees with the results of the 1914 tests. It was further found that for first settle gypsum specimens stored at 100 degrees F and for second settle stored either at 100 degrees or at 70 degrees the addition of 0.1 per cent of retarder or more caused a loss in strength. When no retarder was present the strength of

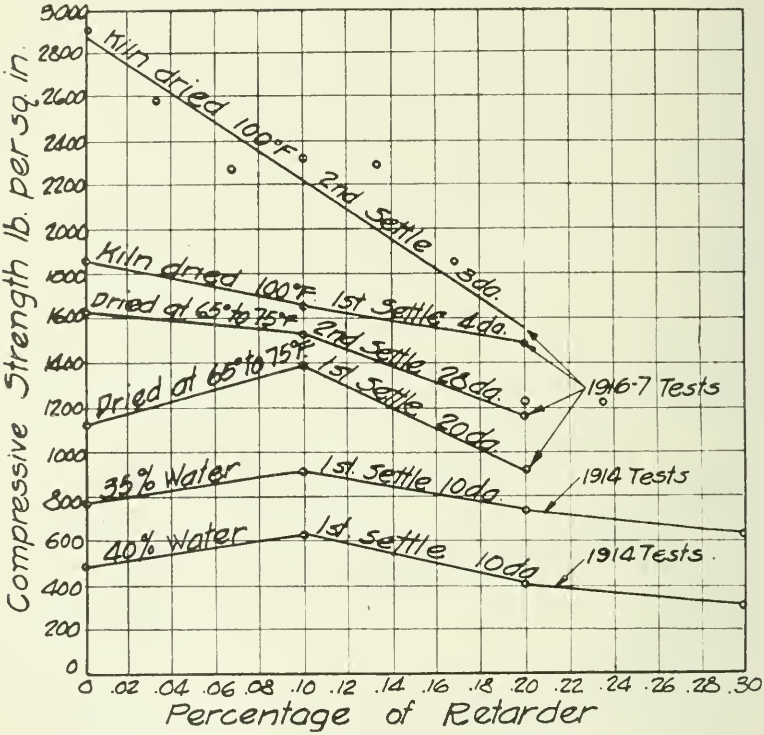


Fig. 26. Effect of Amount of Retarder on Compressive Strength for Various Conditions of Making and Curing

first settle specimens was about two-thirds of that for second settle specimens whether the drying was at 70 degrees or at 100 degrees F. Generally the second settle gypsum lost strength more rapidly with the addition of retarder than did the first settle. However, this was not true in all cases. These results are shown in Fig. 26. Fig. 26 shows also a more rapid loss in strength with addition of retarder for the dry specimens than for those only partly dry.

Modulus of Rupture and Tensile Strength. These tests indicate a modulus of rupture in tension which is fairly high relatively to the compressive strength of the gypsum and which does not vary greatly with the amount of retarder used. The variation of modulus

of rupture with amount of water was greater and was not consistent. The variation in tensile strength with amount of retarder and of water was slight but was quite consistent.

The tests were too few in number to be conclusive. The results of these tests are given in Tables 11 and 12 and Fig. 27 and 28. Table 11 is made up from the 1914 tests but for convenience these are presented with the later tests. Calculations indicate that the tensile stress at first crack in the beams reported in Table 14 ranged from about 400 to 800 lb. per sq. in.

Table 11. Modulus of Rupture of Plain Gypsum Beams; 1914 Tests

Specimen No.	Per Cent of Retarder	Depth of Specimen, inches	Load, lb.	Modulus of Rupture, $\frac{6M}{bd^2}$ lb. per sq. in.
3-1	0	6.02	3,250	355
3-2	0	6.15	3,150	332
3-3	0	6.05	3,120	334
3-4	0.14	5.97	3,360	371
3-5	0.14	6.04	4,310	465
3-6	0.14	6.11	3,810	404

Nominal size of Specimen, 6 in. x 6 in. x 18 in.
Tested on 16 in. span with load at center.
Weight of water used in mixing 35 per cent of total weight.
Retarder is given as per cent of weight of calcined gypsum.
Age at test, 10 days.

Table 12. Modulus of Rupture and Tensile Strength of Gypsum; 1916-17 Tests

Specimen No.	Date Made, 1916	Per-cent-age Gaging Water	Per-cent-age of Re-tarder	Weight of 3 specimens, gm When Made	At Test	Modulus of Rup-ture, lbs. per sq. in.	Tensile Strength, lbs. per sq. in.	Variation from Average Strength Max.	Av.
				Plain Beams, 4x4x24-in. (Modulus of Rupture)					
14AA1 to 4	6/23	36	0.0	...	...	390	...	12.6	6.4
14AB1 to 4	6/23	36	0.1	...	...	493	...	47.5	24.0
14AC1 to 4	6/23	36	0.2	...	...	511	...	29.3	14.3
14BA1 to 1	6/28	33.5	0.1	...	...	464	...	18.9	13.9
14BB1 to 4	6/29	35.5	0.1	...	...	590	...	4.8	3.9
14BC1 to 4	6/29	37.5	0.1	...	...	464	...	16.7	8.3
				Briquettes (Tensile Strength)					
14CA1 to 3	6/27	36	0.0	336	260	...	417	7.9	5.3
14CB1 to 3	6/27	36	0.1	329	247	...	326	4.9	3.4
14CC1 to 3	6/27	36	0.2	322	244	...	304	14.2	9.6
14DA1 to 3	6/30	33.5	0.1	341	260	...	373	11.5	7.8
14DB1 to 3	6/30	35.5	0.1	332	251	...	360	6.4	4.7
14DC1 to 3	6/30	37.5	0.1	320	236	...	281	5.0	3.5

General Notes

For all specimens: Ft. Dodge second settle specially calcined gypsum; dried in kiln at 100 degrees F.; age at test, 7 days.

Making and Storage of T-Beams. All the beams were mixed at standard consistency, molded in wooden forms, and weighed immediately upon removal from the forms and again, in many cases, at intervals before the time for testing. It was found that the actual weight when dry agreed closely with the weight calculated by the method based on the assumption that in the process of

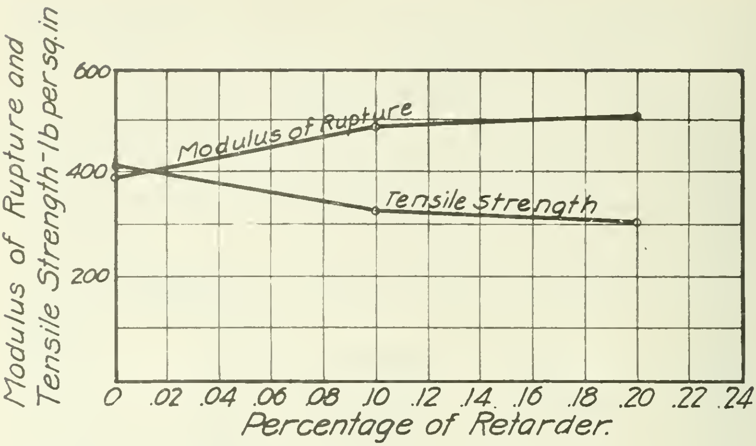


Fig. 27. Effect of Amount of Retarder on Modulus of Rupture and Tensile Strength of Gypsum

hydration all the gypsum becomes $CaSO_4\ 2H_2O$ and that all the excess water is lost by evaporation.

After removal from the forms beams 15AA1 to 15DG3 were stored in an outer shed at a temperature of from 70 degrees to perhaps 90 degrees F. No artificial heat was applied. Usually they were entirely dry before testing. Beams 15EA1 to 15FA3 were made later in the season and because of the low temperature in the outer shed they were stored over the engine room at the United States Gypsum Company's Chicago mill where the temperature was high enough to dry them quite rapidly.

Method of Testing T-Beams. The beams were tested in the small testing machine mentioned on page 421. Beams 15AA1 to

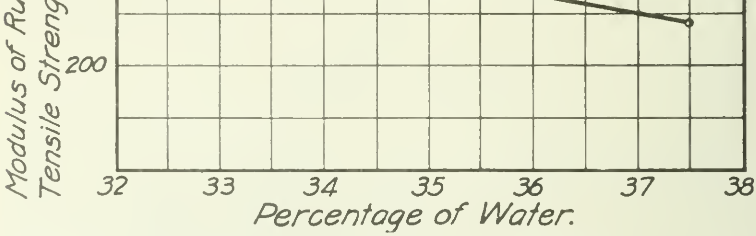


Fig. 28. Effect of Variation in Amount of Gaging Water on Modulus of Rupture and Tensile Strength of Gypsum

15DG3 were loaded at the one-quarter points of the span and Beams 15EA1 to 15FA3 were loaded at two points 10½ in. apart and 26¾ in. (forty-two hundredths of the span) from the supports.

In the first beam tested, No. 15AB3, strain gage readings were taken on the reinforcing bar on both sides of the beam at the one-fourth points of the span and at the center of the span. The stresses found at all of these places were so nearly equal that for subsequent tests it was assumed that the stresses were the same at all positions between load points and the measurements were taken only at the center of the span on opposite sides of the beam.

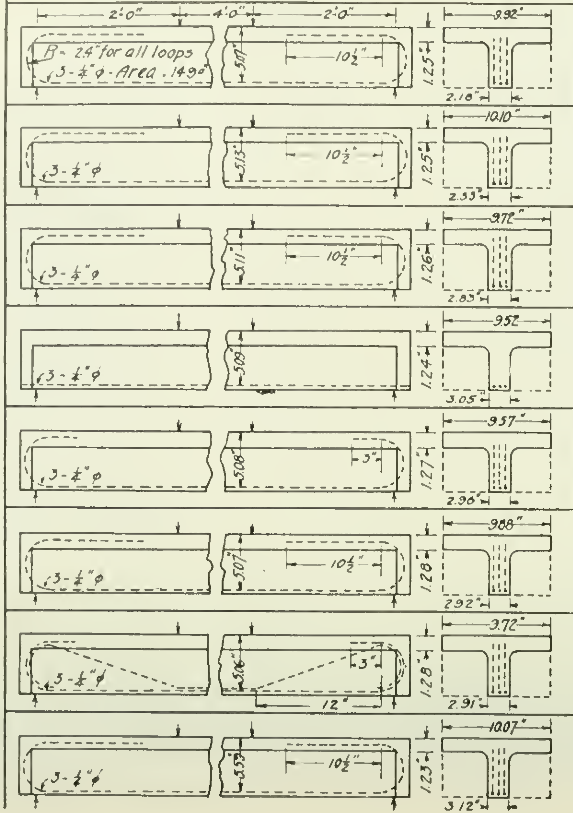
Phenomena of Test of T-Beams. In the beams which were dry when tested, sharp snapping sounds always accompanied the occurrence of cracks. This made it possible to know always when the first crack occurred.

In nearly all the beams tested the first crack to occur was a vertical crack. The calculated tensile stress in the gypsum at the time that the first crack occurred varied from 200 to 5C0 lb. per sq. in., but usually was around 300 lb. per sq. in. The modulus of rupture in tension determined from pieces sawed from the flanges of some of the beams was between 200 and 300 lb. per sq. in. For most of the reinforced beams which had three ¼-in. round bars hooked at the ends but with none of them bent up for web reinforcement. These were tested dry. This vertical crack was followed by diagonal tension cracks. The diagonal tension cracks seemed to have afforded a starting place for horizontal or slightly inclined cracks at the level of the reinforcement, which traveled from the point of starting toward the support, and as a result of which the bars were in many cases stripped from the bottom of the beam. In the beams of the same kind (having three ¼-in. bars), tested wet, diagonal tension cracks, although present, were not so conspicuous a feature of the tests. In beams 15DC and 15DD (reinforced with one ½-in. bar), no diagonal tension cracks developed, although the shearing stresses were as high as those for the beams previously discussed.

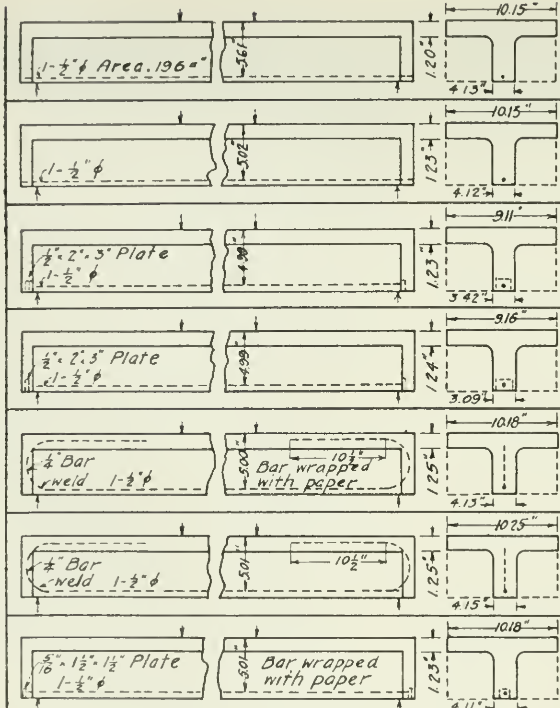
For some of the beams in which the deflection was large, a crack in the horizontal plane at the junction of the stem and slab was found. This crack was located between the load points where the horizontal shear was zero and probably was due to the difference in stiffness of the *stem* from that of the flange. The opening of this crack was noted in one case (Beam 15DG1) to be as much as $\frac{1}{16}$ in.

The phenomena of the tests of the beams having bars bent up as web reinforcement (Beams 15EA1 to 15FA3) were much the same as those of the beams having no bent-up bars except that in the former case the diagonal tension cracks did not lead to stripping of the bars nor result in failure until a much higher shearing stress had been developed than was carried by the beams without bars bent up. In these beams splitting of the stem in a vertical plane along its center frequently was a phenomenon.

f_s = tension in steel, lb. per sq. in. u = bond stress
f_g = compression in gypsum, lb. per sq. in.
v = shearing stress, lb. per sq. in.



Beam No.	Ratio Reinforcement $p=\frac{A_s}{bd}$	Age at Test, Days	Percentage Dryness	Total Load at 1st Crack	Maximum Load: Total	Maximum Load: per sq. ft.	Computed Values at the Maximum Load: f_s	f_g	v	u	$\frac{M}{bd^2}$	Manner of Failure
15AA1	.00269	35	100.0	642	1900	285	30200	536	83	91	65.2	D, S
15AA2	.00262	25	100.0	1030	1790	269	28400	494	79	86	59.5	D, S
15AA3	.00260	27	100.0	685	1900	285	30000	526	92	91	62.5	D, S
Av.	.00265	29	100.0	786	1863	279	29533	519	85	89	62.1	
15AB1	.00260	27	92.0	428	2140	321	33450	587	88	102	69.8	D, S
15AB2	.00254	28	96.5	620	3360	505	52600	912	138	160	112.0	T
15AB3	.00252	25	103.0	858	3090	464	48700	832	135	146	75.5	T
Av	.00255	27-	97.1	635	2863	430	44913	777	120	136	85.5	
15AC1	.00267	29	99.7	642	2360	354	37100	662	81	113	79.9	D, S
15AC2	.00259	29	103.0	642	2100	315	33000	574	71	101	68.1	D, S
15AC3	.00277	30	98.8	642	2360	354	37400	686	89	113	83.8	D, S
Av.	.00268	29+	100.5	642	2273	341	35833	641	80	109	77.3	
15BA1	.00276	34	100.0	578	2510	377	39500	713	80	120	86.5	D, S
15BA2	.00272	31	98.0	835	2300	345	36300	678	75	110	80.1	D, S
15BA3	.00274	31.	96.4	642	2680	402	42600	775	87	128	95.8	T, D
Av.	.00274	32	98.1	685	2490	375	39466	722	81	119	86.8	
15BB1	.00268	27	99.0	750	1760	264	28000	494	58	84	58.3	D, S
15BB2	.00256	31	97.9	685	2250	338	35700	632	74	108	76.2	D, S
15BB3	.00286	32	94.5	792	1930	290	30200	573	66	92	68.6	D, S
Av.	.00270	30	97.1	742	1980	297	31300	566	66	95	67.7	
15BC1	.00257	28	97.3	600	3480	522	55500	953	118	166	119.0	T
15BC2	.00281	31	100.0	792	2360	354	37000	685	94	113	83.9	D, S
15BC3	.00255	30	97.3	920	3860	580	61800	1057	132	195	132.0	T
Av.	.00264	30-	98.2	771	3233	485	51433	865	115	158	111.6	
15BD1	.00282	30	97.2	663	3540	532	56200	1032	118	169	131.8	T, @
15BD2	.00287	31	98.1	642	3430	515	54700	1018	117	164	131.0	T, @
15BD3	.00268	30	101.0	642	3220	484	51400	907	111	154	114.0	T, @
Av.	.00279	30+	98.7	649	3396	510	54100	1019	115	162	125.6	
15CA1	.00264	1	15.2	1930	3530	530	57300	1018	115	152	135.0	T
15CA2	.00265	1	16.3	1930	3690	555	59900	1050	119	158	140.5	T
15CA3	.00265	1	13.7	1930	3260	490	52500	935	105	140	123.5	T
Av.	.00265	1	15.0	1930	3493	525	56566	1001	113	150	133.0	



15DA1	.00346	1	10.3		1160	174	14100	312	28	74	54.8	B
15DA2	.00343	1	9.15	642	940	141	11400	250	23	60	35.0	B
15DA3	.00348	2	10.2	792	1090	164	13350	293	26	69	41.4	B
Av.	.00346	1+	9.85	717	1063	159	12950	185	26	68	43.7	
15DB1	.00349	28	98.0	685	2080	312	25460	562	51	152	99.9	B, D
15DB2	.00344	27	97.5	1280	1840	276	22300	486	45	134	86.6	B
15DB3	.00342	21	103.0	878	1370	206	16500	252	32	100	63.6	B, S
Av	.00345	25	99.5	947	1763	265	21416	433	46	129	83.4	
15DC1	.00383	1	81	1280	3360	540	40800	960	108	245	176.0	P, T
15DC2	.00387	1	10.2	1930	3900	585	47900	1138	127	274	165.0	T, P
15DC3	.00348	1	11.2	1070	3720	558	45500	995	91	271	142.0	T, H
Av	.00373	1	98	1426	3660	561	48066	1031	108	263	161.0	
15DD1	.00382	22	100.8	428	3540	538	43200	1020	116	257	147.0	*
15DD2	.00381	23	95.0	1070	4080	613	49600	1170	131	296	169.0	T
15DD3	.00387	20	98.0	855	4080	613	50100	1180	132	296	172.0	T
Av	.00383	22-	96.9	751	3900	588	47633	1123	126	283	162.7	
15DE1	.00344	1	11.7	428	1270	191	15400	336	30	92	47.5	P
15DE2	.00342	1	10.2	600	1160	174	14100	302	28	84	42.7	P
15DE3	.00349	2	10.2	642	1580	237	19500	420	39	115	59.7	P
Av	.00345	1+	10.7	556	1336	201	16330	352	32	97	50.0	
15DF1	.00342	22	90.4	428	1970	296	24100	512	48	143	73.0	P
15DF2	.00341	24	101.6	365	2080	312	25400	537	50	151	76.8	P
15DF3	.00339	22	99.6	320	1860	280	22500	483	44	136	67.5	P
Av.	.00341	23-	97.2	371	1970	262	24000	510	47	143	72.4	
15DG1	.00343	1	6.6	642	2220	333	27200	592	54	162	84.0	P
15DG2	.00344	1	13.7	855	2430	365	29600	646	59	177	90.2	P, H
15DG3	.00342	1	13.7	1005	2170	326	26400	574	53	158	80.5	P, H
Av.	.00343	1	11.3	834	2273	341	27730	604	55	166	84.9	

Symbols Indicating Manner of Failure

S-stripping. H-horizontal shear at anchor plate.
T-tension. P-bearing pressure at anchored end of bar.
B-bond. D-diagonal tension.

Notes

Circle around symbol indicates doubt.
*-Cutting away gypsum around bar caused eccentric compression producing tension failure in top of beam.

Table 13. T-Beams of 8-ft. 6-in. Span; Results of 1916-17 Tests

Manner of Failure of T-Beams. Six distinct forms of failure were recognized in the tests under discussion. These, together with the symbols used to represent them are: Tension (T), diagonal tension (D), stripping (S), bond (B), bearing pressure (P), and horizontal shear (H). In many instances more than one of these forms of failure were involved in the test of a single beam and it is not possible always to say which was the principal cause of failure. In Table 13 all the factors which appear to have been significant have been mentioned in what is believed to be the order of their relative importance in bringing about failure. It seems that where more than one factor entered into the failure the maximum load carried may have been less than that which would have caused failure by either one of the factors alone.

Horizontal reinforcement is designed to resist the tensile stresses in a horizontal direction. When the total tensile stress developed is great enough to cause the stress in the reinforcement to pass its yield-point a large deflection occurs, and although the beam may not collapse due to the horizontal tension, it is not often that the load can be increased greatly beyond this point, and it seems proper to designate the passing of the yield-point stress as tension failure. This has been done in Table 13.

The horizontal tension and the shearing stress combine to cause a tension in a diagonal direction. To resist the diagonal tension, web reinforcement in the form of stirrups or of bent-up bars is introduced if the shearing stress is likely to exceed certain allowable working stresses. Diagonal tension failure manifests itself in causing cracks which originate usually at or near the level of the reinforcement. For a simple beam they are inclined so that the lower end is nearer the reaction than the upper end. Usually in Table 13 diagonal tension has been indicated as one cause of failure if diagonal cracks were found, even though primary failure may have appeared to be from other causes.

After the formation of a diagonal crack there is a tendency to transmit the shear across the crack through the longitudinal bars. This gives rise to a tendency toward stripping of the reinforcing bar from the bottom of the beam between the crack and the support. This stripping tendency will be greatest just outside the crack and if it becomes severe enough at this point to start stripping, then a similar stress will be caused farther along toward the support and the stripping will proceed with a ripping action toward the support. The diagonal tension cracks, which in themselves may not be sufficient to cause failure, afford a starting place for this stripping action and in no case in this series of tests was stripping observed without diagonal tension cracks having first appeared. Such failures in this series of tests, developed rather gradually and were not sudden in the sense of giving no warning. In some previous tests of gypsum beams (See page 415), however, stripping failure occurred without any indication of diagonal tension having

first appeared. Those failures were very sudden and with no warning.

Bond failure, when not complicated by other factors, manifested itself first by a vertical crack usually almost immediately under the load-point. In such cases the falling off of the load was slight with continued operation of the testing machine after the maximum load had been reached. Such failure was not sudden. When in the same vicinity high stresses in horizontal tension or shear occur simultaneously with high bond stress, a primary failure by bond may result in the formation of diagonal tension cracks, and this, in turn may result in stripping of the reinforcing bars. The only beams which failed entirely by bond without complications of another sort were certain of those in groups 15DA and 15DB, which had as reinforcement one ½-in. round bar. Although for none of the other beams is it indicated in Table 13 that bond was a factor causing failure, it may be that the diagonal tension cracks found in 15BA were caused by incipient bond failure, for it is seen that the bond stresses for beams 15BA were nearly as high as for beams 15DB.

The phenomenon here termed "bearing failure" is probably due to a combination of high compressive, shearing, and tensile stresses, resulting from the pull on the anchorage at the end of the bar, and tending to bring about failure because of (a) excessive crushing under the bearing plate or hook, (b) a shearing off of the end of the stem (termed H in Table 13), or (c) a splitting of the stem in a vertical plane when the bar or a wedge shape piece of gypsum is forced lengthwise through the stem by the tension in the longitudinal bar.

These three methods of failure were recognized in the tests. Compression of the gypsum enters in an important degree into all three methods. When this compression results in the development of a shearing stress large enough to cause a shearing failure, phenomena distinct from the other two occur. This is denoted in Table 13 by the initial "H". This manner of failure was peculiar to the beams having end plates for anchorage of the reinforcing bars. The high bearing pressures seemed more likely in these tests to result in a splitting failure than in a shearing failure. In fact, the high compression and the splitting are so closely related that in Table 13 both are classed as failure due to high bearing pressure.

Tension in Reinforcement of T-Beam. In Fig. 29 the observed stresses have been plotted against the applied loads for certain of the beams. The straight lines representing the computed stresses have been shown also. The observed stresses are seen to be somewhat lower than the computed stresses at low loads. For such loads, however, as those at which the gypsum around the reinforcement had cracked, the curves for the computed stress and those for the observed stress are close together. This may be taken to indicate that for the lower loads the gypsum afforded considerable

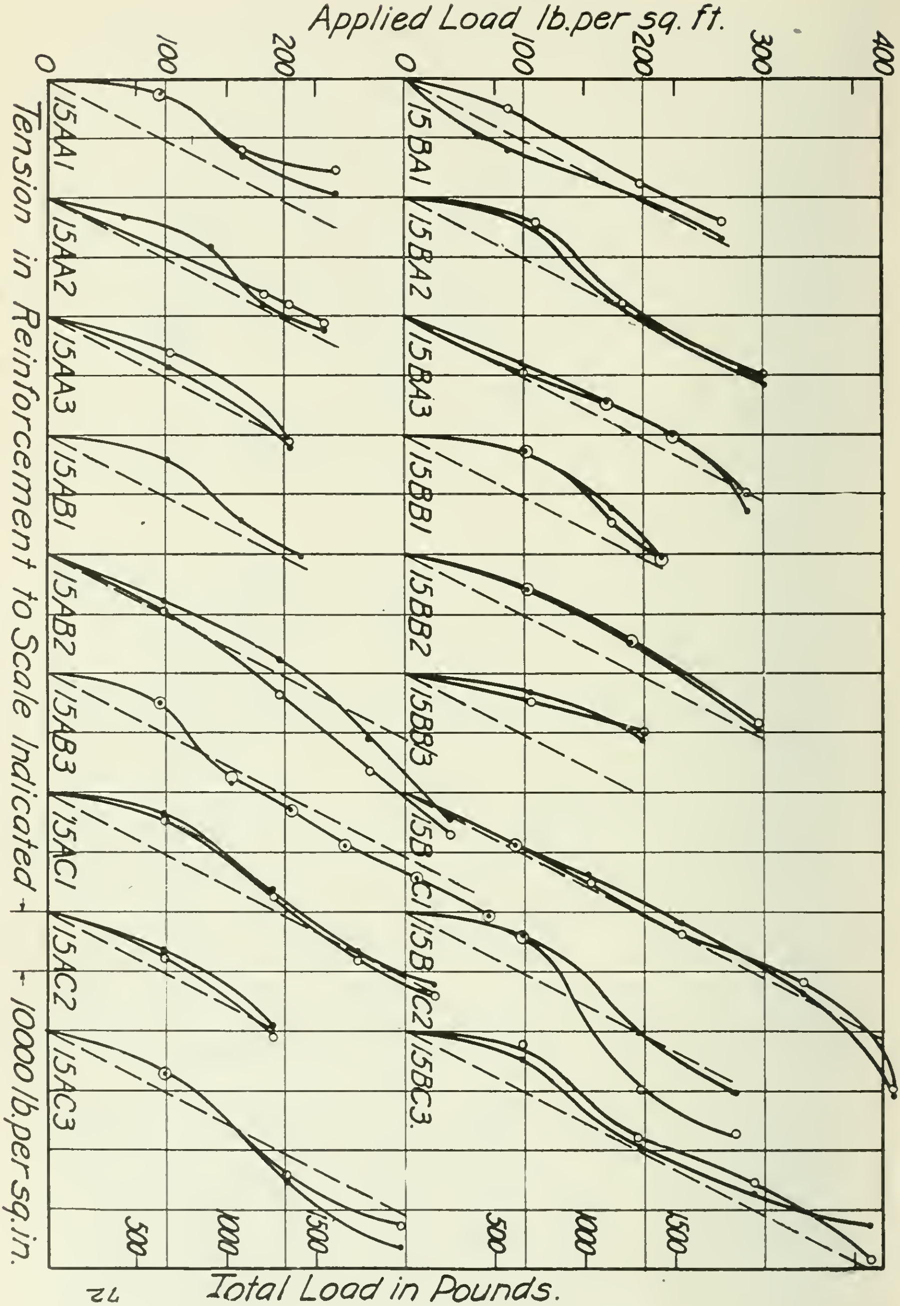


Fig. 29. Load Stress Curves for Reinforcement at Center of Span of Gypsum Beams

resistance to the tensile stresses, while at the higher loads little of this resistance was present.

In Fig. 30 values of $\frac{M}{bd^2}$ in pounds per square inch, have been plotted as ordinates with the observed tensile stresses as abscissas for all the beams having as reinforcement three ¼-in. bars and in which the deformations in the reinforcement were measured. From the relation $\frac{M}{bd^2} = pf_sj$ the values of $\frac{M}{bd^2}$ for observed values of f_s were computed from the known values of p and j. For these beams the value of p (the ratio of the steel area to the area of the rectangle whose width is the flange width and whose depth is the distance from the top of the beam to the center of the reinforcement) averages 0.00268, and j (the ratio $\frac{d-t/2}{d}$) averages 0.89. Eighty-five points, in all, have been determined from the loads and stresses. Of these two fall on the straight line representing the computed value of $\frac{M}{bd^2}$. Sixty-nine points lie above this line, indicating that for these cases the observed stresses were less than the computed stresses, and fourteen points lie below the line.

Stripping and Diagonal Tension in T-Beams Without Bent-up Bars. The beams of groups 15AA, 15AB, 15AC and 15BC were alike except that the width of stem varied. All were reinforced with three ¼-in. round bars having a yield-point stress of about 43,000 lb. per sq. in. Of these the beams with the narrower stems failed by diagonal tension and stripping combined. Those with the wider stems generally carried greater loads and showed a tendency to fail by the stress in the longitudinal reinforcement passing the yield-point. The increase in the width of the stem increases the resistance to diagonal tension at the same time that it increases the resistance to stripping. This makes it difficult to determine which was the primary cause of failure. With one or two exceptions the shearing stresses at failure were low, and the fact that the beams of group 15DD, which had more reinforcement (one ½-in. round bar), carried an average shearing unit stress 20 per cent greater than those in any of the above named groups and failed by tension in the reinforcement without any indication of diagonal tension, failure seems to indicate that in beams AA, AB, and BC, diagonal tension was not the principal cause of failure, although diagonal tension cracks usually were seen before there was any appearance of stripping. It appears likely that the principal cause of failure was stripping on the level of the reinforcement, although probably a contributory cause was the formation of the diagonal tension cracks which appeared in all the beams of groups 15AA, 15AB, 15AC and 15BC and which did not appear at all in beams of the group 15DD. In some of the first named groups tension stresses were so high that tension in the steel also must have contributed

largely to bringing about failure of the beams. These tests leave unsettled the question of what is the proper width of beam to prevent stripping failure, although for beams of this series with three ¼-in. bars the necessary width seemed to be about 3¼ in.

In four different groups (15BD, 15CA, 15BC and 15DD) failure was by tension in the reinforcement at loads, which caused

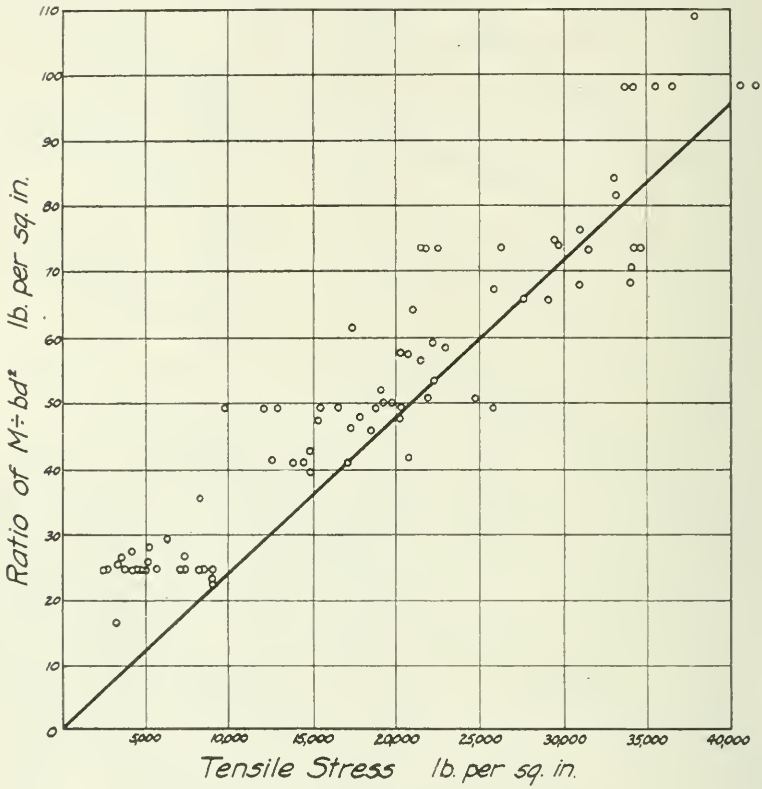


Fig. 30. Values of M ÷ bd² for Various Observed Stresses in Reinforced Gypsum Beams

vertical shearing stresses ranging from 108 to 126 lb. per sq. in. (averages for groups of 3 beams). In group 15BD it is possible that the bending up of one bar near the end afforded sufficient web reinforcement to prevent failure by diagonal tension. In group 15CA, the stem was wider than in any of the previous groups. This fact, together with the large amount of anchorage of the reinforcing bars, may have been sufficient to preclude stripping or bond failure. The fact that this beam was tested wet may also have helped to prevent stripping failure. In the two remaining groups mentioned, 15BC and 15DD, larger bars (½-in. round)

were used and these were anchored by means of end plates. These beams had a larger area of gypsum to resist stripping, and the anchor plate precluded bond failure. Under conditions comparable with those which existed in these tests and where stripping and bond failure are eliminated, failure by diagonal tension in beams without web reinforcement does not seem likely to occur when the shearing stress is 80 lb. per sq. in. or less.

Beams With Bent-up Bars. In beams 15EB1 to 15FA3, two or more bars were bent up at each end of the beam at angles of 20, 30 and 45 degrees. In one group of beams, 14FA1-3, both stirrups and bent-up bars were present. All of the bars had anchor hooks at the ends. All the beams had sufficient reinforcement to prevent tension failure and sufficient anchorage to prevent bond failure.

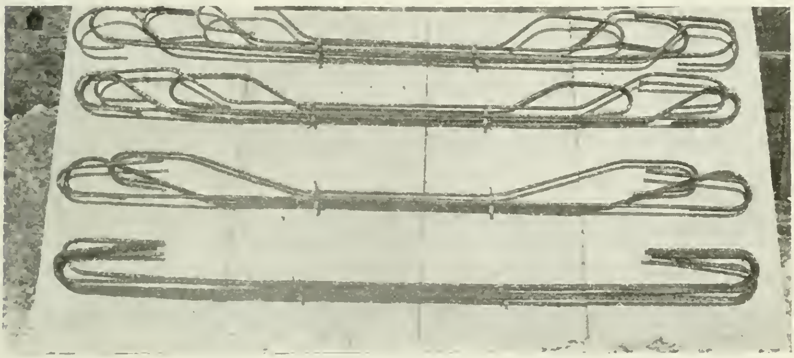


Fig. 31. View of Facricated Reinforcing Units for Gypsum Beams

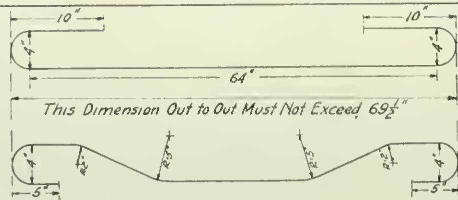
A view of the reinforcing bars as fabricated for the four types of beams employed in these tests is shown in Fig. 31. The type of bar which is straight throughout except for U-hooks at the end is termed a "through bar," to distinguish it from a bar which is bent up at certain places and which is termed a "bent-up bar." The results of these tests are given in Table 14.

In beams 15EA1 to 3 employing only through bars, failure was by diagonal tension, with some cracks resembling stripping cracks. The average maximum shearing strength was 90 lb. per sq. in.

The average shearing strength for all beams with bars bent up was 213 lb. per sq. in. The highest strength (average for three beams) was found in beams with bars bent up at 20 degrees, the first bend being at a distance d from the load-point and the second bend $2d$ from the first bend. In these beams the average shearing strength was 228 lb. per sq. in., or 2.6 times as great as for those with no bars bent up. The lowest average strength for a group with bent-up bars was 2.4 times as great as the average for beams with no bars bent but having anchorage.

Among the earlier tests it was found that splitting of the stem in a vertical plane occurred near the end of the beam. This made it

Beam No	Ratio Reinforcement $p=\frac{A_s}{bd}$	Age at test Days	Percent Dryness	Total Load at 1st Crack	Maximum Load Total	Computed Values at Maximum Load f_s	f_q	v	Bearing Stress q
15EA1	01089	18	96.8	1070	2570	13500	710	95	
15EA2	01089	21	98.4	1860	2570	13500	710	95	
15EA3	01089	14	101.0	1070	2035	10700	560	75	
AV					2390	12500	660	90	
15EB1	.01133				7280	36800	2000	270	367
15EB2	.01133	15	105.2	965	5130	25900	1410	190	
15EB3	.01133	14	101.5	1710	6000	30200	1650	220	
AV					6137	31000	1720	225	
15EC1	.01089	18	94.1	1285	5130	27000	1410	190	
15EC2	.01089				5350	28200	1470	200	1270
15EC3	.01089		101.0	2035	6380	33600	1760	235	
AV					5620	29600	1545	210	
15ED1	.01089	40		1930	6430	33800	1770	240	
15ED2	.01089	40		1070	5780	30400	1590	215	
15ED3	.01089	14	98.4	1905	4930	26000	1360	185	
AV					5715	30100	1575	210	
15EF1	.01089				6000	31600	1650	220	267
15EF2	.01089	17	101.5	428	5130	27000	1410	190	
15EF3	.01089	14	102.0	1930	5250	27600	1450	195	
AV					5460	28700	1500	200	
15FA1	.01133			1930	6200	31300	1700	230	
15FA2	.01133			1860	8140	41100	2230	300	
15FA3	.01133			1350	9200	46400	2530	340	
AV					7845	39600	2150	290	



All stresses given to nearest 5 lb.

In calculations for percent dryness Calcined Gypsum was assumed to contain 6% water

Average pressure "q" is computed from measured stress near U hooks

$$f_s=\frac{M}{A(d-\frac{t}{2})},\quad f_q=\frac{M}{bt(d-\frac{t}{2})}\frac{Kd}{(Kd-\frac{t}{2})},\quad v=\frac{W/2}{b(d-\frac{t}{2})}$$

For method of computing Percentage Dryness see Appendix C Page 1

All failures by diagonal tension

Table 14. T-Beams of 5-ft. 4-in. Span; Results of 1916-17 Tests

appear that possibly failure was due to a high bearing pressure of the hook at the end of the bar against the gypsum instead of to diagonal tension. Accordingly, stress measurements were made in bars at points close to the U-hook, as shown in Fig. 32 in order to determine what pressure was exerted against the gypsum. Measurements of this kind were taken in one beam of each group, that is, one beam for each angle of bend. These measurements showed very low stress in most cases. Only in one case was a high tensile stress found and this high stress was developed after the maximum load occurred and after the load had fallen off to less than one-half of the maximum. If splitting at the end of the bar had occurred before reaching the maximum load in this case, the bar would have let go and the stress could not have been increased after the maximum load. This affords a basis for the conclusion that failure generally was not due to splitting of the beam caused by high bearing pressure under the U-hook. Where splitting of the stem was found for beams with bent-up bars this must have occurred after a primary failure due to some other cause.

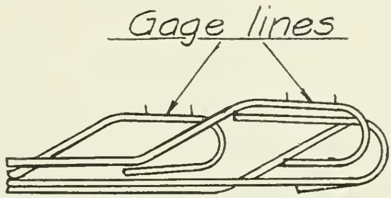


Fig. 32. Sketch Showing Position of Measurements to Determine Amount of Pull on Anchor-hooks

Beams with Bent-up Bars and Vertical Stirrups. In one set of beams, 15FA1-3, fourteen ¼-in. stirrups, as shown in the sketches, Table 14, were used in addition to longitudinal bars of the same size and bent up in the same way as in beams 15EB1-3 and these beams showed an average shearing strength of 291 lb. per. sq. in., or 3.35 times as much as that for beams with only U-hooks and no stirrups.

It seems that in these beams the cross bar at the bottom of the stirrup lay about ¼ in. below the longitudinal reinforcement. This was not a good detail and with more attention paid to securing a direct contact of the cross bars with the bottom of the longitudinal reinforcing bar it is possible that the superior anchorage thus furnished to the stirrup would have enabled the beam to carry a still greater load.

Bond Resistance in T-Beams. Beams 15DA 1 to 3 having one ½-in. plain round bar each (tested at an age of one day while the gypsum was still wet) failed in bond at an average bond stress of 68 lb. per sq. in. This agrees well with the results for pull-out specimens tested when wet (see Fig. 20). Beams 15DB 1 to 3 (same as 15 DA 1 to 3 except that they were dry when tested) failed in bond

at a computed bond stress of 112 lb. per sq. in. In beams 15BA 1 to 3, which had three ¼-in. straight bars with no end anchorage, there was doubt as to the real cause of failure, but there was an indication that high bond stress may have been a factor. The average bond stress for these beams was 104 lb. per sq. in. at failure. The average bond stress developed in beam 15DD 1 at the maximum load was found by measurement (see the following paragraph) to be 107 lb. per sq. in. at one end and 125 lb. per sq. in. at the other end. The average bond stress developed by dry pull-out specimens made at the same (standard) consistency was 534

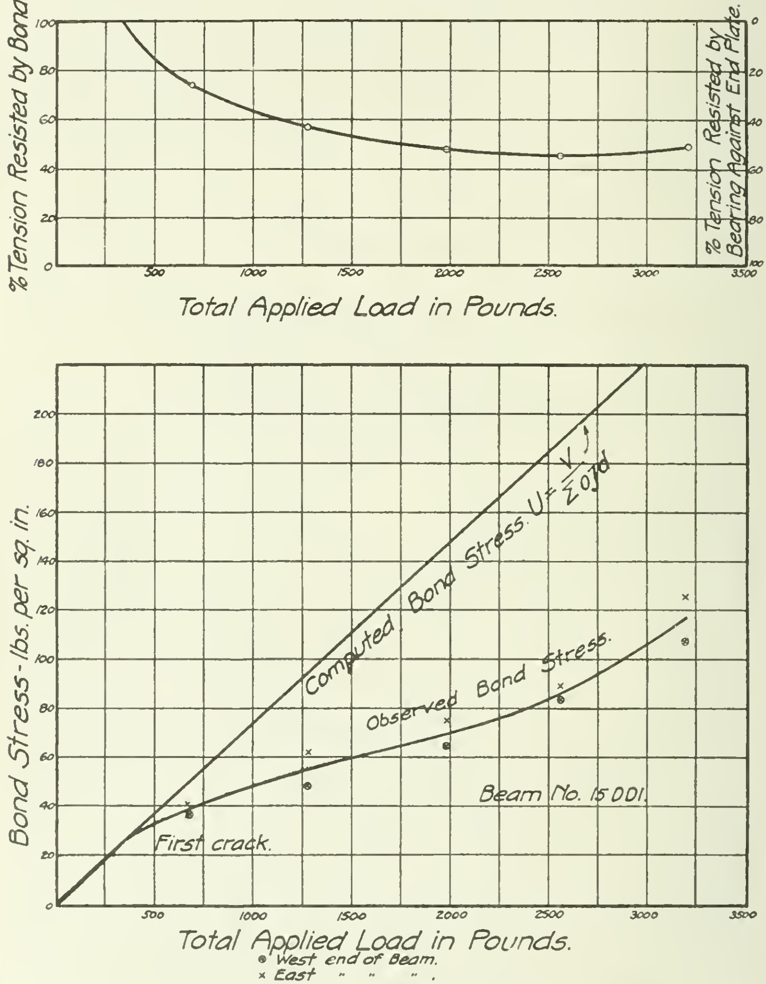


Fig. 33. Measured Bond Stress in Beam 15DD1

lb. per sq .in. While it is recognized that the bond stress developed in pull-out specimens is not strictly comparable with that developed in beams, a much closer agreement is usually found between them than is here indicated. It is apparent that some factor not taken into account affected the bond resistance in the pull-out specimens or the beams or possibly both.

Measurements of deformation were taken on the reinforcing bar in beam 15DD 1 in order to determine the bond stresses developed and to obtain information on the effectiveness of the anchor plates at loads below which the bond strength had been exceeded. The gage lines for these measurements were placed on opposite sides of the bar (which was located on the longitudinal center line of the beam near the bottom) at each of four points of the span, namely, under each load point and at a distance of 7 in. from each support. From the differences in observed stress at the different points of the span the average bond stresses were computed and have been plotted in Fig. 33 against the applied load. For comparison the bond stresses computed by the ordinary formula $u=V/\Sigma ojd$ are shown in the same diagram. Apparently at the beginning of the test a bond stress nearly or quite as great as the computed bond stress was developed. From the load at which the first crack occurred until about two-thirds of the maximum load had been reached the ratio of the measured bond stress to that computed, decreased in general, and at the lowest point slightly less than five-tenths of the computed bond stress was developed along the bar. The fact that the anchor plate became effective at an early stage in the test helps to explain why anchorage of bars is so effective in preventing diagonal tension failure.

The ratio of the observed bond stress to the computed bond stress is the same as the ratio of the tension resisted by bond to the total tension in the bar. This ratio has been plotted in the upper part of Fig. 33 in which it is seen that at all times 45 per cent, or more, of the total tension was carried by bond, and that the largest amount carried by bearing against the end plate was 55 per cent of the total tension.

The highest bond stress observed was 116 lb. per sq. in. (average for the two ends) and it is of interest to note that although the plate had come into action the bond resistance was still increasing when the last readings were taken. It is of importance that the bond stresses and bearing on the anchor plates can both be effective at the same time. This bears out the belief that the maximum bond resistance of gypsum is not likely to be exceeded until after a considerable amount of slip has taken place. Further evidence of this is seen in the fact that in the beams failing purely by bond a load almost equal to the maximum was maintained in some instances with continued operation of the testing machine for a considerable time after the characteristic bond failure cracks had appeared and the bars had begun to slip.

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Recent tests made on reinforced concrete beams by the Bureau of Standards have shown results which are quite similar to these with respect to the amount of the stress developed by anchorage of the bars.

Anchorage with U-Hooks at Ends of Bars in T-Beams. In beams 15DE 1 to 3 and 15DF 1 to 3 the bars were wrapped with paper to within 3 in. of the ends of the beams in order to prevent the development of bond stresses and to cause all the tensile stress in the bar to be resisted by the end anchorage furnished by U-hooks of 4.8 in. diameter. The total horizontal tension in a bar thus is made to equal the horizontal component of the bearing pressure on the hook at the end of the bar against the gypsum. This horizontal component was found to give an average pressure of 2680 lb. per sq. in. for beams 15DE 1 to 3 (tested when wet) and of 3940 lb. per sq. in. for beams 15DF 1 to 3 (tested when dry).

This form of anchorage was very effective. For the most satisfactory results probably the diameter of the U-hooks at the end of a reinforcing bar should have a fixed ratio to the diameter of the bar regardless of the size of the bar used. With the proper diameter of the U-hook a certain length of bar beyond the end of the curve will be required to prevent slipping of the free end of the bar. This also probably can be expressed as a ratio of the diameter of the bar. The most effective diameter of curvature of anchor hook has not been determined but it is probably a sharper curvature than that used in the tests under discussion. The diameter of curvature was 19.2 times the diameter of the bar for most of the beams having U-hooks.

With this diameter of curvature and with a straight piece of the bar extending 4 diameters beyond the hook it was found that there was a slight movement of the end of the bar. It seems likely that the diameter of the U-hook may be reduced and satisfactory results still obtained. With a reduction of the diameter of the hook a reduction in the length of anchorage beyond the end of the hook probably will be justified.

Anchorage by means of Plates at Ends of Bars in T-Beams. Each of the beams 15DG 1 to 3 had one ½-in. bar anchored by means of a 1½-in. square plate rigidly attached at each end of the bar. It was expected that the uniformity of pressure developed in this manner would be sufficient to result in an average bearing strength greater than in the case of beams anchored with hooks at the ends of the bars. Here also the bars were wrapped to prevent the development of bond resistance and the area of the plate was purposely made small in order to insure a failure by excessive bearing pressure on the end plate. The beams were tested at the age of one day while they were still very wet. Failure occurred at an average computed bearing pressure at the ends of these bars of 2660 lb. per sq. in. (found by dividing the total tension in the bars by the area of the anchor plate less the cross sectional area of the reinforcing bar). It was unexpected that the average bearing

strength in this case should not be greater than that for the anchor hooks of beams 15DE 1 to 3.

Beams 15DC 1 to 3 and 15DD 1 to 3 had anchor plates 2 in. by 3 in. but the bars were not wrapped to prevent the development of bond resistance, since in this case it was hoped to cause a diagonal tension failure in order to obtain information on the diagonal tension strength of wet gypsum. In one of these beams (15DC3) failure occurred by shearing of the stem on a plane inclined at an angle of perhaps 5 or 6 degrees with the horizontal. It is not known what angle the shearing stress which caused failure generally made with the horizontal. If, however, this be assumed as a maximum to be 30 degrees the cross-sectional area of the gypsum resisting the shearing stress will be two times the width of the stem times the distance from the bottom of the beam to the top of the anchor plate. Dividing the total pull in the reinforcing bar by this shear-resisting area, a shearing unit-stress of 280 lb. per sq. in. is obtained. This figure is not given as a reliable measure of the resistance to shearing failure of this kind, but as the only available interpretation of the scant data at hand.

Other beams of the DC group than 15DC3 gave indication of this kind of failure, but in the others the tension failure was the most prominent. Although these beams do not serve the purpose for which they were intended they indicate the importance of examining for horizontal shearing stress a design which involves the use of end plates for the purpose of anchorage.

Expansion of Beams with Setting of Gypsum. There was a slight expansion of the gypsum with setting. This was observed only in the upper fibres and seems to have been prevented in the lower fibre by the restraint afforded by the reinforcement. The expansion of the upper surface soon after setting was frequently found to amount to as much as 0.1 in. in the total length of the 8 ft. beams, but seldom more than this. As the beam dried out the expansion partially disappeared and at the time of testing the beam the total change in length probably averaged about 0.05 in.

Accompanying the expansion was an upward deflection which amounted to as much as $\frac{3}{16}$ in. or $\frac{1}{4}$ in. It has been found, however, that this upward deflection may be effectually prevented, where it is desired to do so, by means of a small amount of wire mesh reinforcement placed in the upper flange of the beam.

General Discussion

There are certain features of the results given in the preceding pages concerning which it is desirable to summarize the results of the tests of all four groups. It is not feasible to discuss these subjects in full but a few of the more important of them are here given.

Modulus of Elasticity. The specimens on which the determinations of the modulus of elasticity given in Table 1, and Fig. 5

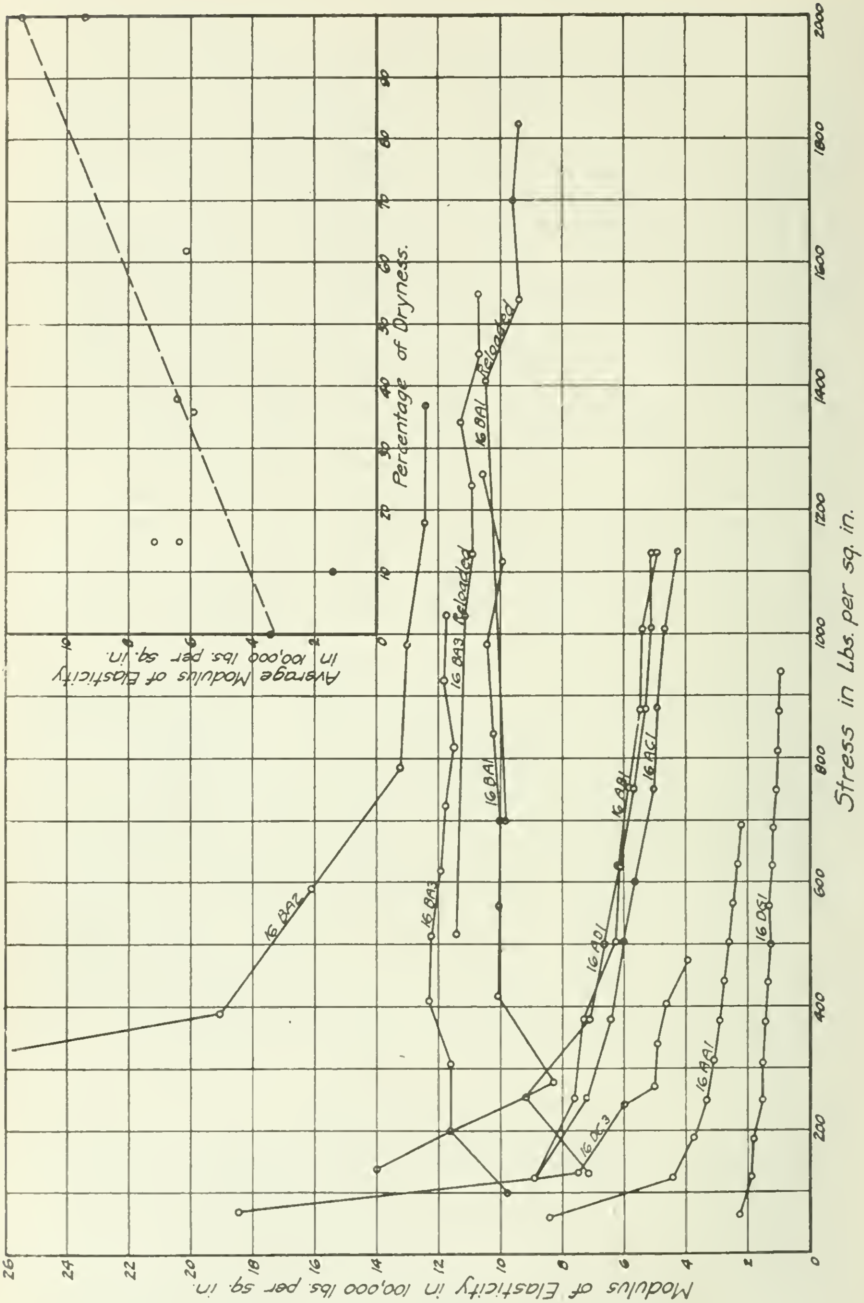

Fig. 34. Modulus of Elasticity for Gypsum Specimens of Varying Percentage of Dryness

were made, were mostly 8 by 16-in. cylinders tested at an age of 10 days. It is apparent from Fig. 13 that specimens so large could not have been dry at this age.

The difference between the stress-strain curve for a dry specimen (tested at 110 days) and one tested at 10 days is brought out in Fig. 4. The dry specimens show a modulus of elasticity of somewhat more than 1,000,000 lb. per sq. in. and the ten-day specimens having not more than 35 per cent of water show a modulus of around 750,000 lb. per sq. in. In Fig. 34 the secant moduli of elasticity for specimens varying in percentage of dryness have been plotted for various loads.* It will be seen that for the dry specimens the modulus of elasticity was nearly constant throughout the range of the loading. For the specimens not entirely dry the modulus decreased with the increase of the unit-deformation much as is frequently found with concrete. In the upper portion of this figure the average moduli are plotted as ordinates and the percentage of dryness as abscissas.

Considerable diversity of values is shown in this diagram, but it seems fair to say that average working values of the modulus of elasticity are 1,000,000 lb. per sq. in. for dry gypsum, and 750,000 lb. per sq. in. for gypsum not less than 50 per cent dry.

Bond Resistance. Certain pull-out tests, and beam tests, have indicated low bond resistance. Pull-out tests for specimens made from first settle gypsum in the 1914 and the 1915 tests showed maximum bond strengths of approximately 200 lb. per sq. in. with an individual specimen running above 400 lb. per sq. in. Beam tests in these groups also gave low bond resistance. The maximum bond strength for beams of first settle gypsum having no anchorage of bars was 129 lb. per sq. in. at an age of 10 days, and 137 lb. per sq. in. at an age of 94 days.

A beam of second settle gypsum in the 1915 tests (Beam 4-26) developed 191 lb. per sq. in. at an age of 10 days, and in the 1916-17 tests pull-out specimens made from second settle gypsum (See Fig. 22) showed an average bond resistance of 500 lb. per sq. in. when dry. However, beams 15DA1-3 (also made from second settle gypsum, tested at one day age (10 per cent dry) showed a bond strength of only 67 lb. per sq. in. and beams 15DB tested at 25 days (99.5 per cent dry) showed only 127 lb. per sq. in. bond strength. Thus, while certain tests have shown high bond strength there is much variation and the data on bond strength are seen to be inconclusive. For all except the very lowest bond stresses anchorage of the bars should be used.

Summary. (1) The rate of drying of gypsum after setting took place was nearly constant until about 87 per cent of the excess water had been evaporated. For 6x12-in. cylinders this required about 20 days. Evaporation of the remaining 13 per cent

*It is recognized that these probably are not true moduli of elasticity since some of the deformations measured were probably plastic deformation. It may be necessary in the future to revise methods of computation to make allowance for this, but at present it does not seem important to enter into this question.

required about 20 days more. This was at ordinary temperatures and humidities. With the temperature raised to 100 degrees F. and relative humidity at about 0.50, the drying time was reduced to 7 days or less for complete dryness.

(2) The weight of hydrated first settle gypsum per cubic foot was about the same as that of hydrated second settle gypsum. The weight of dry hydrated gypsum decreased with an increase in the amount of water used in mixing. The calcined gysum required was about five-sixths of the weight of the dry hydrated gypsum resulting, regardless of the amount of water used in mixing.

(3) The attainment of the maximum compressive strength of gypsum appears to depend upon the amount of drying out rather than upon the age. Increase in strength with age is apparently due to increased drying with age. Small specimens (3x6-in. cylinders) dried at 100 degrees F. showed a temporarily high strength as soon as they were dry. This strength soon fell to about the same as that of specimens dried at ordinary temperatures or of larger specimens dried at the same temperature. The permanent strength of second settle dry specimens made from gypsum mixed at standard consistency and having 0.1 per cent retarder seemed to be about 1900 to 2000 lb. per sq. in., whether dried at 100 degrees or 70 degrees, regardless of the size of the specimen.

(4) When mixed without retarder at standard consistency the strength of the first settle gypsum when dry was about two-thirds of that of second settle gypsum, whether the storage was at 70 degrees or at 100 degrees F.

(5) The compressive strength fell off regularly and rapidly with an increase in the percentage of water used in mixing. For second settle gypsum, 100 per cent dry using 0.1 per cent retarder, the range in strength found was from 2400 to 400 lb. per sq. in. when the water varied from 35 per cent to 53 per cent.

For first settle gypsum about 50 per cent dry, using no retarder, the range in strength was from 760 lb. per sq. in. to 140 lb. per sq. in. when the water varied from 35 to 60 per cent.

A portion of the difference in strength between the second settle and first settle gypsum is undoubtedly due to the fact that the first settle gypsum was only about 50 per cent dry.

(6) Under certain conditions the use of retarder caused a decrease in the strength of the gypsum. For the conditions most likely to be met in practice the use of not more than 0.1 per cent retarder is likely to cause only a slight loss but under certain storage conditions it may even cause an increase in the strength.

(7) The tensile strength of gypsum seems to be from, say 300 to 800 lb. per sq. in. The earlier beam tests indicated that no cracks occurred in the gypsum until the stress in the reinforcement was very high. This was, to a certain extent, true for the later beams, but was less marked than in the earlier investigation. The combination of a high tensile strength with a low modulus of elasticity would be expected to bring about this kind of a result. A part of the

difference in behavior may be due to the fact that the earlier beams were not as dry at the time of testing as were the later ones.

(8) Only a small amount of exposure of dry hydrated gypsum to very moist air was sufficient to reduce the strength of gypsum considerably—but additional exposure even to the extent of soaking the specimen in water had relatively slight effect on the strength.

(9) The use of hydrated lime up to about 4 per cent of the weight of the gypsum caused a marked decrease in the amount of corrosion of the imbedded bar and in the bond strength with steel bars. With larger amounts of lime there was little additional effect on either the bond strength or the amount of corrosion.

The tests indicated a loss of about 3½ per cent of the compressive strength of the gypsum for each one per cent of hydrated lime used. This is true up to 10 per cent of the total weight of lime and gypsum. Ten per cent was the largest amount of lime used.

(10) Corrosion of the reinforcement in roofing tiles which had been in use for four years was neglible where the gypsum had been kept reasonably dry. Where the gypsum had been continually saturated for a considerable time the corrosion was important.

(11) Second-settle gypsum from various mills of the United States Gypsum Company showed a good degree of uniformity in compressive strength.

(12) The tests of the T-beams indicate that the same principles which are used in the design of reinforced concrete beams are applicable to the design of reinforced gypsum beams.

(13) Under conditions comparable with those which existed in these tests and where stripping and bond failure are eliminated failure by diagonal tension in beams without web reinforcement does not seem likely to occur when the shearing stress is 80 lb. per sq. in. or less.

(14) Anchorage of reinforcing bars by means of semi-circular hooks at the ends was fully as effective as the use of plates attached to the ends of the bars for anchorage.

(15) In a test made to determine the effectiveness of anchorage the end plate came into action early in the test. Shortly after the beginning of the test the proportional part of the total tension carried by bond began to decrease and the proportion carried by anchorage increased until at about two-thirds of the maximum load slightly more than one-half of the total tension was resisted by bearing against the anchor plate. From then until failure the proportion carried by bond was nearly constant. It is possible that under some conditions a larger proportion would have to be carried by the anchor plate. The largest average bond stress found for this beam was about 120 lb. per sq. in. and this occurred at the maximum load.

(16) An upward deflection amounting usually to about 3/16 in. and in certain cases to as much as ¼ in., was found in the beams previous to testing them. An expansion of the gypsum dur-

ing the setting or drying process took place and the restraint of this expansion on the reinforced side of the beam seems to be responsible for the upward deflection. It was ascertained that the most of the expansion occurred soon after the first set had taken place and at the end of 24 hours the expansion generally was larger than at any time later.

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Proceedings of the Society

Meeting No. 1045, June 2, 1919.

This was a general meeting of the society and was attended by 51 members and guests. A. S. Baldwin, President, presided. The general subject was "Our Engineers in France." Major R. I. Randolph, M. W. S. E., 335th Engineers, Service Battalion, gave an interesting address, describing his experience in charge of heavy railroad cosntruction in the Toul Sector. Maj. Randolph had charge of the colored troops and presented a poem, which was a tribute to the valor and service of the negro troops. Capt. Paul Hensen, M. W. S. E., in charge of water supply for the second army, described the problems, which confronted the army in the field. This included a comprehensive review of the water resources of the war area of France and the manner of providing the army with ample water supply. Capt. T. McLean Jasper, artillery officer, British Expeditionary Forces, described his experiences, covering the methods adopted by the engineers in the early days before the American forces reached France.

Meeting No. 1046, June 9, 1919.

This was a meeting of the Bridge and Structural Engineering Section. The attendance was 43 members and guests. G. A. Haggander, chairman. J. H. Waterman, superintendent, Timber Preservation, C. B. & Q. R. R. presented a paper on the "Results Obtained from the Treatment of Track Ties and Bridge Timbers." This was illustrated with lantern slides. This paper gave the results of experiments and tests of the various methods of timber preservation and was very complete and instructive.

A joint luncheon of the Western Society of Engineers and the Chicago City Club at the City Club occurred on June 24. This meeting was attended by 100. George H. Mead, President of the City Club, Chairman. The subject of the meeting was Abatement of the Chicago Smoke Nuisance. Joseph Harrington, consulting engineer, formerly advisory engineer of U. S. Fuel Administration, presented the engineering features essential for the control of smoke nuisance. Mr. Harrington emphasized the fact that engineers are agreed that Illinois coal can be burned without nuisance and with economy, provided the proper equipment is installed. Mr. Harrington suggested an expert commission be empowered to enforce the proper requirements and so constituted as to insure proper public opinion. This commission should consist of business men, engineers, employers and representatives of the press. The commission, however, should not take the place of the proper consulting advice essential to success.

Harold Almert, M. W. S. E., formerly with the Illinois Fuel Commission, analyzed the intensity of the problem, stating that industries, although burning 85 per cent of the coal, created only 30 per cent of the coal smoke nuisance. The domestic user burned only 15 per cent of the coal and created 85 per cent of the smoke nuisance. Mr. Almert urged that the smoke nuisance could be largely eliminated if attention was given to domestic use and instructions prepared for the use of householders on how to avoid smoke.

Meeting No. 1047, June 27, 1919.

Fiftieth Anniversary.

The entertainment committee planned an afternoon and evening meeting in commemoration of the fiftieth anniversary of our Society. At the afternoon session there were present 45 members and guests of the Society. Major H. J. Burt, past president, presiding. A brief review of the fifty years of the society's history was presented by the secretary, Edgar S. Nethercut, with special reference to the events of the last ten years and the activities of the engineering societies during this period with plans for the future. A review

of engineering progress for the last fifty years was presented by the following:

S. O. Dunn, editor, Railway Age, Chicago—Progress in Transportation.

J. R. Bibbins, M. W. S. E.—Perfection of Mechanical Apparatus Developed during the last Fifty Years.

J. R. Cravath, M. W. S. E.—Development of Electric Light and Power and the Extent of this Important Industry.

F. F. Fowle, M. W. S. E.—Development of Electric Communication.

John W. Alvord, past president M. W. S. E.—Development of Sanitary Engineering.

At the close of the afternoon session, dinner was served at the Chicago Engineers' Club.

The evening session was called together at 7:30 p. m. E. S. Nethercut, secretary, presided. This meeting was attended by 100 members and guests. The entertainment committee provided a moving picture. Col. H. A. Allen, 108th Engineers, recently returned from France, was the first speaker. Col. Allen described the activities of this regiment in France and outlined the necessity of proper preparedness for the future as a lesson gained from the war. Brief addresses were presented by past presidents of the society: Samuel G. Artingstall, John F. Wallace, W. L. Abbott, J. W. Alvord, H. J. Burt, Isham Randolph, Ralph Modjeski, Andrews Allen, Albert Reichmann, Charles B. Burdick.

Messages of greetings to the society were received from Hiero B. Herr, R. W. Hunt, W. H. Finley, Edward C. Carter, E. H. Lee, W. D. Jackson and B. E. Grant. The society was particularly honored by the letter from J. E. Blunt, honorary member. Mr. Blunt participated in the formation of the society and presented the first paper. A letter was also received from J. W. Weston, secretary of the society from 1889 to 1894. Music was furnished by an orchestra. A. W. Dilling and the Universal Quartet conducted the singing. On motion duly made and seconded the secretary was instructed to send a cablegram to G. A. M. Liljecrantz, who for many years was active in the affairs of the society. At the conclusion of the program refreshments were served by the entertainment committee.

EDGAR S. NETHERCUT, *Secretary.*

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JOURNAL OF THE

WESTERN SOCIETY *of* ENGINEERS

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Western Society of Engineers Celebrates Its Fiftieth Anniversary

Half a Century of Progress Reviewed Before a Notable Gathering of Members and Guests on June 27 and 28, 1919, Inclusive

ON June 27 and 28 the Society celebrated its fiftieth anniversary. This celebration took the form of an afternoon and evening meeting on the first day. The afternoon session was presided over by Henry J. Burt, past president. A brief review of the fifty years of the Society's history was presented by the secretary, Edgar S. Nethercut, with special reference to the events of the last ten years and the activities of the engineering societies during this period with plans for the future. Coincident with the life of the Society, progress in the arts and sciences has been marked and a review of this progress for the last fifty years was presented by the following:

S. O. Dunn, editor, *Railway Age,* Chicago—Progress in Transportation.

J. R. Bibbins, M. W. E. S.—Perfection of Mechanical Apparatus Developed During the Last Fifty Years.

J. R. Cravath, M. W. S. E.—Development of Electric Light and Power and the Extent of this Important Industry.

F. F. Fowle, M. W. S. E.—Development of Electric Communication.

John W. Alvord, past president, M. W. S. E.—Development of Sanitary Engineering.

These reviews appear elsewhere in this issue.

At the close of the afternoon session, dinner was served at the Chicago Engineers' Club.

At the evening session the secretary, Edgar S. Nethercut, presided.

The program for this evening's session included a moving picture, singing and refreshments, provided by the entertainment committee.

In the fall of 1917 the Western Society of Engineers, in order to give evidence of the interest which it had in the engineering regiments being recruited for the Great War, presented to the First Regiment, Illinois Engineers, the national and regimental colors. This regiment was mustered into the national army as the 108th Engineers and had recently returned from France with a splendid

record. Col. Henry A. Allen of the 108th Engineers delivered an inspiring address on the value of preparedness and the activities of his command at the evening session.

The poem by James N. Hatch also proved to be one of great interest and was appreciated.

The list of past presidents of the Society is a notable one and includes men who have occupied important positions in our commonwealth and who have greatly contributed to the advancement of the profession. This list of past presidents is as follows:

Mason, Roswell B.	Powell, Ambrose V.
Paine, Charles	Chanute, Octave
Chesbrough, E. S.	Finley, William H.
Smith, Wm. Sooy	Modjeski, Ralph
Pope, Willard S.	Parkhurst, H. W.
Cregier, DeWitt C.	Carter, Edward C.
Williams, Benezette	Arnold, Bion J.
Wright, Augustine W.	Abbott, W. L.
Artingstall, Samuel G.	Loweth, C. F.
Gottlieb, A.	Allen, Andrews
Corthell, E. L.	Alvord, J. W.
Cooley, L. E.	Chamberlain, O. P.
Randolph, Isham	Armstrong, W. C.
Hunt, Robert W.	Reichmann, Albert
Herr, Hiero B.	Lee, E. H.
Horton, Horace E.	Jackson, Wm. B.
Wallace, John F.	Grant, B. E.
Johnston, Thos. T.	Burt, H. J.
Noble, Alfred	Burdick, Charles B.
Bates, Onward	

While all of the living past presidents were not able to be present, the members present at the evening session were favored with remarks by many. These included Samuel G. Artingstall, John F. Wallace, W. L. Abbott, J. W. Alvord, H. J. Burt, Isham Randolph, Ralph Modjeski, Andrews Allen, Albert Reichmann, Charles B. Burdick.

Messages of greetings to the Society were received from Hiero B. Herr, R. W. Hunt, W. H. Finley, Edward C. Carter, E. H. Lee, W. B. Jackson and B. E. Grant. The Society was particularly honored by the letter from J E. Blunt, honorary member. Mr. Blunt participated in the formation of the Society and presented the first paper. A letter was also received from J. W. Weston, secretary of the Society from 1889 to 1894. On motion duly made and seconded the secretary was instructed to send a cablegram to G. A. M. Liljecrantz, who for many years was active in the affairs of the Society.

On Saturday, June 28, a basket picnic was given by the entertainment committee at the Dunes on Lake Michigan. The games and bathing proved very enjoyable. This natural park adjoining our city is an ideal place for an outing.

The Western Society of Engineers

Résumé of the Activities of the Society From Its Organization as the Engineers Club of the Northwest to the Present Time

By Edgar S. Nethercut, Secretary, M. W. S. E.

THE Western Society of Engineers had had a continuous history since its organization on May 25, 1869, as the Civil Engineers Club of the Northwest. We are honored now by having among our members two who participated in the proceedings of the society during the first years of its existence; J. E. Blunt, honorary member, read the first paper on Railroad Frogs on December 13, 1869; Alonzo W. Paige, honorary member, read the second paper on the Mohawk and Hudson Railroad on January 10, 1870.

The Club was organized in response to a call from Roswell B. Mason, Mayor of Chicago. This call was responded to by R. B. Mason, I. C. Chesbrough, H. A. Gardner, Charles Paine, L. H. Clarke, William Bryson, K. F. Booth, William H. Clarke, Max Hjortsberg, George C. Morgan, A. L. Van Meenen and L. P. Morehouse, and a meeting was held on May 25, 1869.

The early history of the club is fully described in an address by L. P. Morehouse at the reminiscence meeting held on March 24, 1909. Referring to the gentlemen mentioned above, he says:

> Of these gentlemen, besides myself, I think Mr. Morgan is the only one still living. The last time I saw him—about a year ago—he was expecting to go to California, and my impression is that he is there now, building waterworks as he did in Chicago.
>
> For the benefit of those who do not know who these gentlemen were I will state that R. B. Mason at that time, and for some years afterward, was called the dean of the engineering profession in the northwest. He was probably the most widely known there of any civil engineer. He came to Illinois in 1851 as chief engineer of the Illinois Central Railroad and for six years was building that road. After its completion he went into business as a contractor. He built one or two roads in Iowa, and then returned to Chicago to practice his profession in a general way. In 1869 the principal work he was engaged on was the construction of the Dunleith and Dubuque bridge over the Mississippi river, which, I think, was begun in the spring of that year and completed in December. The next year he was made chief engineer on the work of deepening the Illinois and Michigan canal so as to take the water from the Chicago river and provide a new method of disposal of the sewage of the city of Chicago. He was mayor of Chicago at the time of the

great fire, having been elected a year after our Society was organized.

I. C. Chesbrough, a brother of E. S. Chesbrough, was connected with the engineer department of the city of Chicago. H. A. Gardner was chief engineer of the Michigan Central Railroad. Charles Paine was division engineer on the Lake Shore and Michigan Southern Railway. I will state here that Mr. Paine was the father of this Society, and while the invitation to attend the first meeting went out in the name of Col. Mason because he was so well known, Mr. Paine was really the founder. As many of you know, he filled some very important positions in the engineering world. He left Chicago to become general superintendent of the Lake Shore and Michigan Southern Railway, resigning that position to take that of chief engineer to build the West Shore road.

L. H. Clarke was chief engineer of the Illinois Central Railroad. He afterwards filled several positions of a similar character, going from the Illinois Central in 1877 to the Lake Shore and Michigan Southern as chief engineer. At one time he was city engineer of Chicago. Mr. Bryson was connected with the engineer department of the City of Chicago. Mr. Booth was chief engineer of the Chicago and Alton Railroad. W. H. Clarke was connected with the engineering department of the City of Chicago, and was the engineer in charge of the first tunnel that was constructed under the lake. E. S. Chesbrough, city engineer, was the designer of the tunnel and advanced what was then considered the wild idea of going out two miles under Lake Michigan to obtain pure water for Chicago. I should like to say that he was present at our first meeting, but the records do not sustain me.

Mr. Hjortsberg was chief engineer of the Chicago, Burlington & Quincy Railroad. Mr. Morgan was in private practice, I think. Mr. Van Meenen was chief engineer of the Chicago and Northwestern Railway. Mr. Morehouse was assistant engineer on the Illinois Central Railroad.

These are the people who were present at the first meeting and when we remember that it was forty (now fifty) years ago, it gives some little interest to the matter.

Engineering societies in America had their inception in the organization of the Boston Society of Civil Engineers, organized on July 3, 1848. This society has had a continuous existence for seventy-one years without change of name. It is the engineering society of New England, and in this respect has been a regional society.

The American Society of Civil Engineers was organized in New York on November 5, 1852. There was a lapse of twelve years without meetings, but in 1867 the society was revived and

since then has had a continuous progress. This society has become a national society and from it has branched off other national societies, such as the American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, and others. There are now over fifteen national societies. The American Institute of Architects was founded in 1867.

The Civil Engineers Club of the Northwest was the third engineering society to be formed. It was based on the broad meaning of the words civil engineer and has always contained in its membership engineers of all branches. There is one personal connection which is of interest. E. S. Chesbrough was a member of the Boston society in its early days and he was also active in the A. S. C. E. while in New York. While not present at the first meeting of the Civil Engineers Club of the Northwest, he was an early member. He read a paper on June 6, 1870, on the Conveyance of Water Under Navigable Streams. Mr. Chesbrough was president from June 9, 1873, on the resignation of Mr. Paine, until June 19, 1877, and again from August 3, 1880, to January 2, 1882. His relation to municipal engineering in Chicago was most important—Chicago under him became the best sewered city in United States and the water system was far in advance of other cities. The sewers put in by Mr. Chesbrough are still in use, but far beyond their capacity.

W. M. R. French came to Chicago as an assistant to Mr. Chesbrough. He presented a paper on Methods of Surveying Irregular Subdivisions on May 8, 1871. Mr. French later took up art and to him is credited the Art Institute of Chicago.

In the early record of papers presented are to be noted the following names, in addition to those mentioned above: William Bryson, 1870; H. W. S. Cleveland, 1871; S. S. Greeley, 1871; M. N. Forney, 1871; W. W. Wright, 1873; W. L. B. Jenney, 1873; E. L. Cortell, 1874; O. Chanute, 1874.

In 1880 the name of the society was changed to the Western Society of Engineers and the society reorganized.

"This had only been effected after a hard campaign on the part of the promoters, for the opposition comprised many of the prominent members, who undoubtedly by long association as members of the Civil Engineers Club of the Northwest looked upon that organization as amply broad enough for all future development. C. W. Durham devoted himself in every way possible to the end of winning the fight, and many well remember his burst of indignation when, at the meeting to vote upon the question, many of the older members whose presence was seldom recorded, appeared upon the scene to vote against the project. I do not think that the Society ever came nearer adopting current political methods to secure an end than in the final efforts to change the organization of the Society. None can now doubt the wisdom of the change although only theoretically was the field enlarged, but a change in policy and effort were soon developed with results which speak for themselves."

There are no officers of the Civil Engineers Club of Northwest living today. The presidents of the Western Society of Engineers who have died are: R. B. Mason, 1892; Chas. Paine, 1906; E. S. Chesbrough, 1886; William Sooy Smith, 1916; Willard S. Pope, 1895; D. C. Cregier, 1898; Benzette Williams, 1914; Augustin W. Wright, 1918; A. Gottlieb, 1894; E. L. Corthill, 1916; L. E. Cooley, 1917; Horace E. Horton, 1912; Thomas F. Johnson, 1909; Alfred Noble, 1914; Octave Chanute, 1910; H. W. Parkhurst, 1906.

Of the past presidents these are living: Samuel G. Artingstall, Isham Randolph, Capt. Robt. W. Hunt, Hiero B. Horr, John F. Wallace, Onward Bates, Ambrose V. Powell, William H. Finley, Ralph Modjeski, Edward C. Carter, Col. Bion J. Arnold, W. L. Abbott, C. F. Loweth, Andrews Allen, J. W. Alvord, Col. O. P. Chamberlain, W. C. Armstrong, Albert Reichman, E. H. Lee, William B. Jackson, B. E. Grant, H. J. Burt, Charles B. Burdick.

Space will not permit referring to those others who have served as officers and who largely served the Society and community. I would, however, refer to the secretaries because of the service these men rendered: L. P. Morehouse, 1869-1888; L. E. Cooley, 1888-1889; John W. Weston, 1889-1894; Thomas Appleton, 1894-1895; Chas. J. Rooney, 1895-1896; Henry Goldmark, 1896-1897; Nelson L. Litten, 1896-1901; J. H. Warder, 1901-1915; E. N. Layfield, 1915-1917.

Special notice should be given to Mr. Morehouse because of his long service and care during the years of small beginnings, and his foresight. In one address he said:

"I cannot refrain from adding at this time that in all the years of my connection with this Society and my association with the different members, many of whom I have known so well, it has been one of the greatest pleasures of my life to see, not only the physical works which many of these gentlemen have superintended or carried out—the works which will remain after they have passed away—but to have associated with these gentlemen who have made a record in their personal lives, and placed before the community the evidence that engineers can make, not only monuments of stone and of metal that shall endure, but shall make, can make, do make character for themselves, the remembrance of which will not be forgotten by their friends or by any community in which they may live."

Mr. Weston was secretary at a period of reconstruction during which time the society acquired permanent headquarters. Concerning his work he said:

"I believe I shall be borne out by all those who did hard practical work for the upbuilding of the Society, in the few years prior to the World's Fair, in the assertion that those years were strenuous ones, filled with many disappointments, but also with many encouragements. It was intensely gratifying to note the rapid development of the organization when once a start had been

made, but the start was a long and hard pull. Referring again to the difficulty of securing members, it occurs to me that at one time it was noted that quite a number of members of the American Society were located in Chicago, and it was deemed advisable to look them up and invite their co-operation with the Western Society, an effort that had not been made previously. From more than one of these gentlemen I learned personally that they deemed their membership in the American Society sufficient for all practical purposes, and that they saw no benefit to themselves in accepting our invitation. This will throw further light on this problem, in that our field from which to draw membership was included in a sense in that of the American Society, and that this discrimination, so long as it lasted, militated against the numerical growth of the younger Western Society."

J. H. Warder, we all know, was the man who guided the society into the period of its present activities.

PRESENT QUARTERS.

For some time prior to 1908 the Society had two rooms, Nos. 1734 and 1741, on the east side of the Monadnock Block. One of their rooms is now occupied by the secretary. The first meeting of the society in the new and present quarters was on September 2, 1908, C. F. Loweth, president, presiding. The library became more accessible in the new quarters and the new meeting room, seating 190, added to the convenience of the society. For many years the secretary's desk was on the west side of the building and, incidentally, I do not see how Mr. Warder or Mr. Layfield could do the work they did do, considering the hot summer sun and other inconveniences.

NOTABLE PAPERS.

Among the notable paper delivered before the society were the following:

O. Chanute—Gliding Experiments, 1897; Recent Progress in Aviation, 1910.

Onward Bates—Arbitration, 1912.

Ralph Modjeski—The Celilo Bridge, 1912; The Thebes Bridge, The Metropolis Bridge, 1918.

W. L. Abbott—Central Station Economies, 1910.

B. J. Arnold—Subways and Railroad Terminals, 1914.

Hugh L. Cooper—Water Power Development of Mississippi River Power Co., 1912.

W. O. Lichtner—Construction Management, 1915.

A. H. Young—Industrial Personnel Relations, 1919.

C. P. Stemmetz—Future Problems of Electrical Engineering, 1913; also papers from 1910 to 1918.

Col. W. V. Judson—Engineering in War, 1915.

J. C. Kelsey—The Relation Between the Banker and Engineer, 1911.

D. W. Mead—Cause of Floods and the Factors that Influence their Intensity, 1913.

C. D. Kettering—The Automobile Power Plant, 1918.

M. E. Cooley—Determining a Reasonable Charge for Public Utility Service, 1914.

Langdon Pearce—The Sewage Disposal Problems in U. S. and Abroad, 1911.

W. S. Potter—Manganese Steel, 1909.

Capt. H. B. Sauerman—Fortifications, 1916.

CODE OF ETHICS.

A committee consisting of H. B. Herr, J. W. Alvord, C. R. Dart, Peter Junkersfeld and C. F. Loweth prepared a code of ethics for the Society which was presented in March, 1917. After letter ballot it was approved and adopted on June 18, 1917, with only a very small change from the code prepared by the committee. This code is distinct from most codes—in two particulars. It is stated in the affirmative manner, and it is the first that I know of that places the emphasis on the engineer's responsibility to the public as a public servant. This code of ethics has been favorably received and is now being copied by other societies. The relation of the engineer to the profession is aptly stated in its concluding paragraph:

"To recapitulate, the ethical standards of the engineering profession should be those of a fraternity. The engineer should recognize that he is endowed by the profession and the state with specialized knowledge for peculiar, judicial and responsible public service involving the life, safety, comfort and convenience of his own and coming generations, and that in response to these he should so conduct himself as to be appreciative of his indebtedness to his profession for his opportunity, and make return by every effort, by a life of special usefulness devoid of unseemly greed, and filled, if possible, with a multitude of those small courtesies, the practice of which encourages the spirit of forbearance and is helpfully conducive to the fine art of living well together."

LICENSING OF ENGINEERS.

During the year 1914 much consideration was given to the subject of licensing of engineers, and while the sentiment of the Society was divided as to whether this was proper or not, it was decided that under the provisions of the architect's license law structural engineers were unfairly treated. An effort was made to have the architect's law modified, but this was not successful. There was then prepared a law licensing structural engineers which went into effect on July 1, 1915. This law has been faithfully administered and has resulted to the benefit of the profession and the proper protection of the public. It was amended at the present session of the legislature, but in no wise changing the requirements except by reducing the fees.

Illinois, I think, was the first state to provide a license act. Since then a number of others have adopted laws and made them cover the entire field of engineering. Whether this is wise or not is yet to be seen. The indications are that it is not wise, unless the laws be uniform. Registration will give ample protection to the public, and on this ground only should laws be enacted.

100-FOOT STANDARD OF LENGTH.

A committee was appointed in 1907 to prepare a copy of the U. S. Standard of Length for the use of the City of Chicago. After numerous delays permission was given to place it in the new city building. The 100-foot standard was installed in November, 1913. It was tested by the Bureau of Standards and approved. The standard was made of steel 2"x½"—102 ft. long, made in six pieces and welded together. The total cost was $230.99. The installation of this standard was very creditable to the Society and to the committee, which consisted of G. A. M. Liljencranz, C. D. Hill and A. C. Schrader.

WASHINGTON AWARD.

John W. Alvord, a past-president, on January 6, 1916, addressed a letter to the Board of Direction and suggested the establishment of an honor award by the Western Society of Engineers. Included in this letter is the following:

"I should be pleased if the recipient of such honor be not limited by Western Society membership, or in fact be restricted by any society or locality requirement. The only qualifications suggested are that he be an engineer of some reasonable degree of professional skill or administrative attainment. It would appear that the award will serve its purpose wisely if at times it is worthily bestowed upon comparatively little known instances of public and professional devotion, as well as at other times upon more conspicuous services.

"I trust, therefore, that the Western Society of Engineers, through its Board of Direction, may be willing and enabled to administer some programme of this kind in such manner and in such instances as from time to time may seem to the Board of Direction best and most fitting, and for the purpose of enabling the Society to have an income sufficient to at least make a beginning, I take pleasure in donating to it, unreservedly, the sum of One Thousand Dollars ($1,000.00) in securities."

Acting upon the suggestion of Mr. Alvord, the board appointed, on January 21, 1916, a committee to submit a report to the board on the best method of administering the "Honor Award" provided for by the fund given to the Society by Past-President Alvord. This committee consisted of Messrs. W. B. Jackson, chairman, C. F. Loweth and C. D. Hill. The report of this committee was received and adopted by the board on December 13, 1916.

In accordance with the plan adopted, the American Society of Mechanical Engineers, the American Institute of Electrical En-

gineers, the American Institute of Mining Engineers and the American Society of Civil Engineers appointed two representatives each to serve on the commission.

The award for the year 1918 was made to Hon. Herbert Clark Hoover for the achievements as chairman of the Commission for the Relief of Belgium, 1914-1917, and for his work as the Food Administrator of the United States, 1917-1918. The bronze placque prepared by the Committee on Design is now on display in our rooms. It will be presented to Mr. Hoover as soon as he can designate a convenient time. C. F. Loweth is now chairman of the award commission.

SOCIETY INTROSPECTION.

During the last five years considerable thought and discussion have been given to the functions of an engineering society. This has not been confined to any locality but has been quite universal. Constructive criticism is at all times proper. The changing conditions of the engineer have been more marked recently; his importance to the community is being recognized, and I am glad to say the engineer is now more ready to do his civic duty than ever before. These conditions require a larger response if the engineer is to maintain the standing in which the successful termination of the war has placed him. The engineering society must also respond to new and greater duties.

For nearly a year committees of the four Founder Societies have been studying this problem, and recently the progress reports of these committees have been presented. The outstanding features are the proper function of the national societies and the local societies and the relation that should exist between them.

It is a fact that the growth of the Western Society of Engineers has not been notable during the last ten years. During this period the national societies have expanded by creating local sections and in this way created competition and a loss to the local societies. Recently it has been recognized that this competition should not continue, but by coöperation stimulate to the growth of both.

In the local society we have personal contact with one another; problems and achievements can be presented and discussed; social relations established, and the merits of the individual can be determined. These include personal assistance in the technical achievements and also in the economic conditions under which we must serve. The local society is the place where the engineer can do his best in matters of local public service.

Locally, the engineers, architects, contractors and industrial managers should be united in one body for the sake of effective work. In technical matters we will continue to take interest in the problem peculiar to our specialty, but in the past this has been on too narrow lines. Now is the time for broadening rather than contracting our information and interests. An all-inclusive society can maintain a program of technical meetings so as to include not only the special subjects but also the broad fundamental engineering problems.

In civic matters, because of the division into small societies, we have made little progress. Instances have been had when opposing views have been placed before the public, which have only resulted in confusion and discredit. Why should we have in Chicago thirteen sections of national societies, two societies to enforce special laws, the Western Society, a state society, and a society non-technical, but interested in the business conditions of the engineers, all working with little coöperation and in conflict in certain matters?

In order to coördinate the work of the technical men in the Chicago area there was organized about a year ago, The War Committee of Technical Societies of Chicago. This committee is composed of representatives of nineteen societies in Chicago. F. K. Copeland is chairman. The first work was to assist the government in the prosecution of the war. It became a center for all calls from the government and greatly assisted in getting the proper engineers and technical men for war service. It also gave a common meeting ground on equal footing for the engineers, architects, constructors, etc. Joint meetings were held at which time the larger matters of common interest were presented. At the close of the war the committee decided to continue and changed its name to the General Committee, Technical Societies of Chicago, for the purpose of promoting the interest of the technical man and of the public in technical matters.

This informal committee has been a success in bringing us together. The number of the members amount to about 5,000, allowing for duplicate membership. It has been estimated that there are about as many more in the Chicago district who should be definitely coördinated in a society.

An all-inclusive society can and will stimulate the growth of the national societies as now organized, and become the feeders to these societies. It should not be considered advisable to do away with the local sections of the national societies, for these have a proper field. They should properly represent the technical division of the local society. The recommendations of the committee of the national societies provide for such local societies. They also provide for state councils to consider and act on the public welfare of the state and the relation of the engineer to this. Also a national council made up of representatives of the state councils and of the national societies.

This program is the result of study on the part of many men. It is one the Western Society may join in. Because of our standing, equipment and organization we may well become the center about which an all embracing local society may be formed and I believe we can have at least 5,000 joined together in such a society.

Origin of the Society

Oldest Member of the Society and Only Living Participant in its Formation Sends His Greetings and Best Wishes

JOHN E. BLUNT is the oldest living member of the Western Society of Engineers and the only one living who participated in its formation. Mr. Blunt was unable to be present at the fiftieth anniversary meeting but forwarded a brief account of how the Society was organized. He says:

"It may be interesting to some of the younger members to learn of the early history and inception of our Society. As I am the oldest member and the only one living who participated in its formation I will endeavor to give its origin.

"Col. Roswell B. Mason, then chief engineer of the Illinois Central Railroad, had his private office in a building which stood on the southwest corner of Lake Street and Dearborn Avenue. Walter Katte, then engineer of the Keystone Bridge Company, had an office on the same floor. L. P. Morehouse, then of the Illinois Central, Charles Paine, then chief engineer of the Lake Shore Railroad, K. F. Booth, then of the Chicago & Alton Railroad, R. J. McClure, then of the Chicago, Burlington & Quincy Railroad, and I, as resident engineer of the Galena Division of the Chicago and Northwestern, frequently met in April and May, 1869, with Mr. Katte at Col. Mason's office and discussed the project of forming an engineers' club. With other engineers it was decided to form a society and call it the Engineers' Club of the Northwest. A charter was obtained and the first meeting was held in May, 1869. From this beginning the Western Society of Engineers was formed and it has had fifty years of success.

"I am very sorry I cannot be with you on the fiftieth anniversary, but, being in my ninetieth year, I have decided to remain in southern California. You have a very attractive program planned for it. I know you will have a very interesting reunion and hope the days will be all that one could desire. With kind regards and best wishes to all."

RESUME OF THE ENGINEERING SERVICE OF JOHN ELLSWORTH BLUNT FROM JAN. 1, 1850, TO MAY 1, 1906.

John E. Blunt was born on December 25, 1829, at Brainerd, Tenn. Most of his education was obtained from his mother until the age of 16; then he went to Burr Seminary at Manchester, Vermont; then to Phillips Academy at Andover, Mass., and then spent two years in Putnam Scientific at Newburyport, Mass.

During 1850 he was rodman and assistant to B. C. Morse, engineer of the Northern Division of the Western & Atlantic Railway, the state road of Georgia. On January 1, 1851, he went to Huntsville, Ala., and entered the first engineers' corps on the Memphis & Charleston Railroad and was levelman on preliminary and

location of the line from Huntsville to Stevenson; after which he had charge of a party on a preliminary line to Memphis via Decatur, Tuscumbia and Lagrange.

In 1853 he located the line from Huntsville to Decatur, twenty-four miles, and had charge of grading and bridging and retraced the old railroad from Decatur to Tuscumbia, which was built in 1832. All work of grading was done by plow, pick, shovel, wheelbarrow and dumpcart, and moved slow, with Irish and negro labor.

In 1854 he located the line from Tuscumbia to two miles west of the Mississippi state line, a distance of ninety-four miles from Huntsville, where a party from Memphis met him. In 1854 his headquarters was moved to Dickson, twenty miles west of Tuscumbia, where he remained until September, 1857, when the track forces met at the junction point in Mississippi after six years and seven months' work. This is now a part of the Southern Railroad.

From 1858 to 1860 he was chief engineer of the Georgia Air Line Railroad, from Atlanta to Greenville, S. C. He made one location from Decatur to the South Carolina line, one from the Georgia Railway in Atlanta to the South Carolina line, and another in North Atlanta to Greenville, S. C., which line was built after the Civil War and is now also a part of the Southern Railroad.

On July 1, 1862, he came to Chicago and entered the service of the Galena & Chicago Union Railroad with headquarters at Evansville, Wis. He relocated and had full charge of the construction of the Beloit and Madison Railroad from Magnolia to Madison, Wis., completing it in September, 1864, when he returned to Chicago. In the meantime, the C. & N. W. Railway, having acquired the Galena Ry., he was appointed resident engineer of that division which comprised 301.44 miles, with 30 miles of second track from Chicago to Turner.

In 1871, on October 20, business being poor and wages low, he accepted the position as chief engineer with a syndicate in Chicago that was building quite a number of roads in Illinois—the Chicago & Iowa; Pekin and Southwestern; Chicago & Paduca; Wabasha & Zumbrota, and others, all of which at this time form parts and branches of main lines. He remained with the syndicate until January 1, 1878, when the president of the Santa Fe, W. B. Strong, asked him to make an examination and report on the condition of that road, with such recommendations as to its improvement as the examination might suggest. The road at that time extended from the Missouri River to Pueblo, Colo. He spent January and February going over the entire road on foot and otherwise, and a report was ready the last day of February, 1878. Two months later he was invited to take charge of the maintenance of way of that road, but being in the service of the C. & N. W. Railway, declined.

On March, 1878, he returned to the service of the C. & N. W. Railway and was stationed at Winona, Minn., and placed in charge of the engineering of the Winona and St. Peter Division and the location and construction of all new lines to be built in Minnesota

and South Dakota. The Winona & St. Peter Division had 330.48 miles of main lines and branches, and he built 236.20 miles of branches with 754 miles in South Dakota, making 990.20 miles added to the mileage of the C. & N. W. system, besides making great improvements on the Winona & St. Peter.

On October 30, 1888, he was appointed chief engineer of the C. & N. W. Ry. and came to Chicago. He was chief engineer until January 1, 1900. During this period second track construction was pushed, grades were reduced, alignment improved, permanent bridges built on 520 miles of the lines in Illinois, Iowa and Wisconsin, and 1,352 miles of line were added to the mileage of the road. Track elevation was begun in 1898 and twenty-four miles of single track were elevated by November, 1899.

On January 1, 1900, he was made consulting engineer and spent the time until May, 1906, in prospecting for new lines and such other duties as the president of the road desired. At that date he was retired as pensioned consulting engineer after fifty-five years of engineering work; thirty-eight years with the Northwestern, six years with a syndicate and eleven years in the South before the Civil War.

Some of his associates in his long and successful engineering career were John B. Turner, president; E. B. Talcott, superintendent, and W. S. Pope, chief engineer, of the Galena & Chicago Union; E. H. Johnson, chief engineer of the C. & N. W. Ry.; John M. Whitman, general manager; S. Sanborn, general superintendent; W. A. Gardner, president, and others who have passed beyond, and Marvin Hughitt, chairman of the board.

Auto-Suggestions

By James N. Hatch

I WAS asked by the program committee to write some verse for the celebration—something appropriate to the occasion they said,—something that will have the engineering story in metaphor and rhythm. Perhaps the program committee do not know that people do not write verse about things, but that the muse whispers to them her message and the versifier writes down what he hears.

So when I was asked to write something for this fiftieth anniversary celebration I listened for the whispering notes that would be appropriate for the occasion. I thought perhaps there would be woven for me a little garland of flowers from which I could throw bouquets at those who have gained distinction and honor in the engineering field. But no such garland was given me.

Then I thought maybe I could be given a message of song that would praise all, both great and small, who have contributed in the weaving of this wonderful engineering fabric that you have heard unfolded by other speakers, but again I was disappointed.

Then I went out into the woods where the birds were singing and the crickets chirping and all was merry and mirthful, but I heard no message that I could transcribe into an engineering eclogue.

I walked beside the placid lake when the moon rose out of the waters and I heard the voice of the mermaids on the summer night, but their siren song gave me no inspiration that I could weave into verse. And I was wellnigh in despair when a voice came to me out of the stillness and said to me, "Why look among the birds and the flowers and the waters for the inspiration that you are seeking. Is it not the hum of machinery, the clatter of riveters, the shrieking whistle and the whirring vehicles that must hold the message for the engineer?"

"Listen," the voice said to me, "to sounds of the buzzing commercial activities for your message; to the sound of traffic of the great city for which the engineer has furnished the locomotion; to the thunder of the rolling mill and the roar of the blast furnace. Look on the magic lights of the city streets and then you will find your inspiration. From thence will come the voice the engineer can understand and that you can transcribe."

Then I listened to the whirring sounds of commerce, to the sounds of machinery and the muse spoke.

On the bank beside a river,
  Where the weeds and thistles grew,
Lay the wreckage of a flivver
  Red with rust and wet with dew.
All its flitful days were over,
  Never more o'er hill and plain
Would the little tin clad rover
  Honk its merry honk again.

"Little Liz I guess you're done for,"
Said I to that hunk of tin,
"The last laurel you have won for
Uncle Henry's now cashed in,
With lean gas they have inspired you,
But you've served your last Ford joke;
You were tired and they retired you,
You have spoken your last spoke."

Then imagine my amazement
As I turned to walk away,
After making this appraisement,
To have heard that lump of clay
Speak to me, and say, "O mortal,
In your vain conceit now learn
That you've only reached the portal,
Where you can real things discern.

"Who are you that in derision
You should make a joke of me?
You who cannot see the vision
That portrays my destiny;
In the same old mold you're molded
As was Adam years agone,
With the same conceit infolded
That has held since mortal dawn.

"You've a mind somehow connected
To your bifurcated frame
By which all things are directed,
To your glory or your shame;
But you haven't changed your stream line,
Or the mixture of your gas,
Or the ratio of your gear teeth
Since Eve was a bonnie lass.

"You are here today, tomorrow
Your existence here may end;
Few of days and full of sorrow
That is what the stars portend,
For suppose you get a puncture,
Or your engine misses fire,
Then it's all up at that juncture,
For you have no extra tire.

"All the years of your existence,
Though they be three score and ten,
Seem a strife for mere subsistence
Each against his fellow men;
Centuries of accumulation
Help the general working plan,
But change not the situation
Of the individual man.

"Solomon is always cited
As the wisest of the seers,
And the wisdom he indicted
Has stood steadfast through the years,
Yet with all his wise precision
Known to mortals near and far,
Lacking still was that rare vision
That could build a motor car.

"You may call me just a flivver,
But I mind not cold or heat,
Haven't any torpid liver
Or a heart that skips a beat;
I'm the product of the ages;
Since the first inventive mind
Wrote his thought on history's pages
Has my destiny been signed.

"Each one of the countless legions,
Who have lived in other years,
When they left these mundane regions
Passing from this vale of tears,
Left some bit of added knowledge
Till there was a storehouse vast
Of the wisdom of the ages
Growing out of all the past.

"You, the living, may contribute
Just a very little part;
But the past makes this exhibit
Of rare industry and art.
One man could not in a lifetime
Build a replica of me,
Yet it takes just forty seconds
In a modern factory.

"While men live they fight and jangle
Each against his fellow man,
Leaving in a hopeless tangle
Many worthy things they plan.
So man's work in its relations
To its worth may not appear,
Until after the carnations
Long have blossomed o'er his bier.

"I am the reincarnation
Of a thousand, thousand minds,
Each one in its right relation
Each one adding what it finds,
From the stone age and the cave man
Down through all the years that are
Have the parts been slowly building
That now make the auto car."

Progress in Transportation

Construction and Intensive Development of Existing Lines Featured the Progress of Rail Transportation During the Last Half Century

By Samuel O. Dunn, *Editor, Railway Age.*

FIFTY years ago when the Western Society of Engineers was founded there were only fifty thousand miles of railways in the United States. I say "only fifty thousand miles." If you should say that in any other country you would evoke a smile, because that is as many miles of railroad as there are in any other country now. I was taking a dinner with the acting general manager of the Great Western Railway of England last December when it was my privilege to be abroad. He asked me something about the Norfolk & Western Railway—asked me if it was a large road. "Well," I said, "not a very large road—about two thousand miles." There were a number of English railway officers sitting around the table and they all began to laugh. It dawned upon me that a railroad of about two thousand miles over there was an extremely large system, larger in proportion than a road over here of ten or twelve thousand miles.

The difference between the attitude of the British railway officers and the American railway officers toward a road of any given size is, I think, a description of the difference between the things that the engineers have had to do over there and the things they have had to do in this country, for English railroads were built through countries that were already settled, where the industries were already developed. On the other hand, the business of our railroads and of our railroad engineers was not to provide transportation for communities, producing centers that already existed, but to provide the means for creating the communities and the means of production.

In the first half of this fifty years the engineers of our railroad systems were engaged chiefly in locating and constructing new lines. I say chiefly. Of course, the lines that already had been built were in the process of intensive development. But between 1870 and about 1895 we built approximately 140,000 miles of new railroad in this country. In 1869 the first transcontinental line to the Pacific Coast was finished. Practically all of the railroad development in this Western territory has taken place since that time. The skill with which the railroad engineers of that earlier period did their work is strikingly indicated by the success with which the railroads that they laid down at that time have been developed. Those earlier lines are the great railroad systems of today. The first one of them, the first trans-continental line built, the Union Pacific, is undoubtedly today the most successful of our Western railroads financially.

The latter half of this period of fifty years has been more largely a period of intensive development of the railroads. It has

not been so much a matter of locating and building new lines, although there has been much of that, as it has been a matter of developing the older lines in order to enable them to give better service and to render that service more economically. In fact, the railroad engineers of this country have met the conditions with which they had to deal as well as have those of the railroads of any country, which is conclusively demonstrated by the fact that their work enabled our roads to move a ton of freight one mile, cheaper than any other railroads.

When I speak of railroad engineers, I am referring not only to the civil engineer, who has had charge of the construction and maintenance, but also to the mechanical engineers who have designed the construction and looked after the maintenance of our locomotives. There are no other railroads which have carried the development for the purpose of securing economy in operation so far as ours. I think we all know how that has been brought about, by reduction of grades, by elimination of curvature, by addition of more powerful locomotives and larger cars.

When the Interstate Commerce Commission was established and began to compile really reliable and complete statistics regarding our railroads, the average tons hauled per freight train was about 175. Since then the average tons per train has increased to about 700 tons. That, to my mind, is perhaps the most striking demonstration of the success with which the railroad engineers of this country succeeded in developing means for handling traffic economically.

When I speak of the work of railroad engineers I necessarily include the work of their many men who have not been directly connected with the companies. Of course, the engineers of the railway supply companies have had a large part in developing new equipment and new devices, which have been used on the systems for the purpose of making them more efficient and economical. Many consulting engineers have had a great part in the development and construction of our great bridges.

The present period marks a crisis in the history of the railroads of this country. I suppose there is no question more prominently in the minds of our people, and especially of those more directly interested in the railroad matters, than the question of what is going to be done with the railroads within the next year? Every question of railroad development in this country hinges upon that. I think, perhaps, you could make no better test of any plan for the future disposition of the railroads which might be offered than to attempt to determine what opportunity the particular plan would give to the engineers to do their work better than they have been able to do it in the past.

The great problem we have got to face is that of securing economical operation and development of these railroads, with labor costs and material costs higher than they ever have been before. That means that we have got to work up means of economizing in the use of labor and economizing in the use of materials, and

that is essentially an engineering problem. So far as I am concerned, I confess I look into the future with considerable misgiving. I cannot believe, however, that the people of this country will fail to appreciate the imperative need of adopting measures which will enable the expansion and development of these railroads. No country on earth more greatly needs good, economical and adequate railroad service, and I feel that we surely are going to show enough intelligence to adopt some plan which will enable the engineers of this country to go on with the development of the railroads along the lines that the country needs.

Development of Sanitary Engineering

The Past Fifty Years Has Witnessed the Complete Development of Sanitation as We Understand It

By John W. Alvord, *Past President,* W. S. E.

I RECALL when I was a boy that my father's house had neither running water nor bathroom or sanitary appliances of any kind; was provided with kerosene lights, and in the community in which we lived I think it was safe to say that nearly all of the better class of people lived in the same way, and they all thought they lived in pretty nice homes too. Looking back, I do not think that I lived in a manner that was not reasonable for the times, and yet I recall that I was twenty-one years old before I lived in a house with bathroom. I presume some of the older engineers here will bear me out that they too can well remember the first bathroom to which they had access, with anything like modern plans. This is striking, because we find our soldier boys complaining, universally complaining, that in France, even in large towns, they find none of the sanitary conveniences to which they had been accustomed at home. Sanitation, therefore, as we know it these days, has come down well within the fifty years' history of this society. I might say, perhaps, that 98 or 99 per cent of the sanitation of the present it is the creation of the last fifty years.

The problem of sanitation is a very old one. Hypophetes of the Christian era first pointed out the fundamental laws of pure health, pure food, pure water and pure soil, and so consistently did he practice his own precepts that he lived to the ripe old age of one hundred years. But it took centuries of involuntary application to shake the idea that epidemics are of celestial origin. That was the period of chaotic conditions. Then we come to the middle of the sixteenth century when Catro first announced the theory of contagious diseases, and then the interval following that to the date of the discovery of the specific germs of disease. This last discovery came about in the early eighties and revolutionized at once the whole conception of sanitation. You will recall, perhaps, if I illustrate by stating that at that time, and for some time later, and traditionally even existing at the present time, the theory was

that it was created by sewer gases, which were the bane of everybody at that time. The discovery of the specific germ that is conveyed more often through food and drink, at once changed our whole attitude towards the question of sewer gas. We began then at once intelligently to clean our water and our food and to some extent clean our air.

Now the sanitary profession has put into practical application the work of cleaning our water—we began early with an introduction of filter systems, filtering large community supplies. These have been developed in this country until the large proportion of the population of this country is now supplied with filtered water, the large proportion of the city communities, I should say. We also introduced the careful inspection and the guarding of our foods. That has not been so much the work of the civil engineer except through processes of refrigeration and other work of that kind. We also developed out of the crude earlier practice, and contemporaneously with the practice abroad, the purification and treatment of domestic wastes. This has been an exceedingly interesting field to a large number of workers, and while it cannot be said that we have yet produced wonderful results, or reduced it to an exact science, great improvements have been made in the recent years. This is a very interesting subject, and all of these developments deserve more time than I am able to devote to them.

It is almost a romantic story when we come to look back at it and come to realize that within your own professional life all this has come about. The distribution of water to every house only became practical through the cheapness and efficiency of cast iron pipe and it was only since about 1880 that a water works system in communities became general. Prior to that time there had been notable water works systems in some of the large cities, but in 1850 there were only sixty-eight water works in this country. In 1880 there were only six hundred and twenty-nine. In 1891 there were about two thousand and in 1900 about thirty-five hundred. I have not been able to get the estimated number at the present date, but it must be well over four thousand or forty-five hundred.

The increase in the number of years estimated as the average life of a man has been very remarkable. In the beginning of the eighteenth century, from 1825 to 1830, it was increased to about 32 years. In 1867 it was estimated to be about 37 years. About 1900 it was estimated in the vicinity of about forty years, and I have not had the time available to gather the statistics to date, but it is notable that the death rate of the large cities of this country from typhoid fever has fallen under five per hundred thousand living. Less than twenty or twenty-five years ago that was up to 50, 75, 100 and in extreme cases, 125 deaths per hundred thousand. Typhoid fever has, therefore, ceased to be a disease to be dreaded. We have it almost within complete control, and in the light of the Black Death and cholera which devastated Europe in the Sixteenth Century and was perhaps responsible directly or

indirectly for the reduction of one-fourth of all the lives, it will soon be a forgotten disease. Some years ago I collected a few notes on this subject with the idea of writing something about it, but the question of professional work has always presented itself and prevented my doing so.

One other interesting thing, however, that I uncovered at that time, which I happened to run across in referring to these notes just before noon, is this definition of an engineer by Marcus Vitruvius, who wrote one hundred fifty years before Christ. He defines what an engineer should be, and I couldn't help but take the opportunity to read it to you, because it struck me as being pretty good:

"He should be a good writer, a skillful draughtsman, versed in geometry and optics, expert at figures, acquainted with history, informed on the principles of natural and moral philosophy, somewhat of a musician, not ignorant of the sciences, both of law and physics, nor of the motions, laws and relations to each other of the heavenly bodies. * * * Moral philosophy will teach him to be above meanness in his dealings and to avoid arrogance. It will make him just, compliant and faithful to his employer and what is of highest importance, it will prevent avarice gaining an ascendency over him for he should not be occupied with thoughts of filling his coffers, nor with the desire of grasping everything in the shape of gain, but by the gravity of his manners and a good character, should be careful to preserve his dignity."

Development of Electric Light and Power

With Zero as the Starting Point Fifty Years Ago, the Present Extensive Use of Electric Light and Power is the Best Evidence of the Development of this Art

By J. R. Cravath, M. W. S. E.

THE electrical section was the first of the "sections" of the Society. The Society was operated previously as a general engineering Society without sections. It is interesting to note that the section idea has taken hold of the whole Society. The subject of development of electric light and power generation, transmission, distribution and use might be dismissed very briefly by saying that practically the whole development has taken place within the last fifty years. In other words, zero was our starting point fifty years ago, as far as practical application was concerned. It is probable all of this development has taken place easily within the memory of nearly every man in this room.

First, in the seventies, the electric motor began to be developed, but in the absence of the systems for generating and distributing and transmitting, it was not used until later to any extent.

In the late seventies the arc lamp began to come into use. Some of the earliest work done by Brush and others was closely followed in the early eighties by Edison's work in the development of the incandescent electric lamp and direct current distributing systems for light and power.

In the late eighties the electric railroad began to take practical form and use. Also in the late eighties and early nineties alternating current transmission and distribution began to come in, and with that a great stimulus in electrical development because of the flexibility which alternating current gave in transmission. The immense high voltage networks for distributing electrical energy, both at high and low voltages, are practically a development of the present century. That is, we had very few high tension networks covering large areas at the beginning of this century.

At the present time the generally accepted method of driving machines in all of our large industries is by electric motors, whether the primary electrical energy is generated at the central station miles away, or in the central plant which is a part of the factory, makes little difference, but the fact is the actual transmission of power around the factory and application to the machines in nearly all large industries is by electric motors.

Electric lighting, as we know, has practically supplanted everything else in our large centers and a great many of the small towns. The development of electric lamps particularly has been very rapid and there have been a series of rapid evolutions that I may speak of briefly. As I mentioned before, the open arc lamp came in in the late seventies. That was followed about ten or fifteen years later by the pure carbon enclosed arc lamp and a little later by

the flame arc lamp, in which the carbon is impregnated with various salts to give additional light giving qualities to the arc. However, that never assumed a large place in the electric lighting field. At the present time the principal survivor in the arc field is the luminous arc lamp which is used extensively in street lighting.

In the incandescent field we had originally the vacuum bulb lamp with the carbon filament. That was followed with a metallic filament lamp in vacuum. That was later followed by the tungsten lamp in vacuum and that by the present development of the tungsten filament lamp in a nitrogen gas filled bulb, or some other inert gas. All of these things have taken a high degree of scientific research and research is essential to all these matters of rapid progress.

Perfection of Mechanical Apparatus Developed During the Last Fifty Years

By J. R. Bibbins, M. W. S. E.

WE receive somewhat of a shock in reflecting that, within this magic fifty year period practically the entire science of thermo-dynamics and electro-magnetism has been developed. Recreate the situation at the Centenial Exposition as datum. Twenty years later at the World's Fair, we all eagerly examined the first two phase direct-connected steam generating unit. Within this period, development has witnessed the advent of the steam turbine, the heavy-duty gas engine and producer and the use of by-product gases from blast-furnaces and coke ovens, the high-vacuum condenser, the water-tube boiler, the mechanical stoker and the entire system of electrical distribution and transmission to great distances. Of course, some of the elements of these systems were known before, notably the turbine of Hero of Alexandria, 120 B. C., but the entire commercial development has come during this time.

In 1900 the first steam turbines were being developed in very small sizes; 400-500 kilowatts was the limit. Previously the British had developed the little yacht "Turbinia" and later the destroyer "Viper" and "Cobra," both fitted with steam turbines. They were able to make the then astonishing speed of 34 knots. If I am correctly informed, our giant warships are designed for nearly this same speed today.

The discovery of the curious phenomenon of "cavitation" in the "Turbinia" practically brought about the necessity of reduced propeller shaft speeds, and that again fitted in with the necessities of steam generating plants where it was necessary to direct-connect electrical generators. Then, too, boilers which used to be installed in quite standard units of 200 to 250 horsepower have grown until now they are mounted in double-ends form, with a tremendous combustion chamber, almost ideal in its design, and capable of ratings of 3,000 horsepower under mechanical stoking and forced draft. Formerly, in a steam power plant, the engine room was the largest part of the plant; now, the boiler room commands the largest space. In fact the practice swings perhaps too far toward excessive concentration in the engine room through the use of the steam turbine. Later, expansion has taken place, giving more room, both horizontally and vertically; for the turbine is such a compact type of prime mover that the very architectural design of the building makes it quite a simple matter to provide all necessary space.

High Density: These large units have been accelerated by the high density of usage in all of the materials used in the turbines and generators, high current densities in the generator windings, steam pressures of 200-250 pounds, super-heats of 200 degrees or more, vacuua, ranging up to 29 inches or more, (corrected to sea-

level), high rates of heat transmission, not only in the boiler but also in the condenser tubes, and finally in the very high rates of coal burned per square foot of grate area, through the perfection of mechanical stoker and forced draft; also in the development of insulation and ventilation, which alone has made possible in these great units the high current densities of the generator windings and in the apparatus for the transmission of the power up to very high potentials in excess of 100,000 volts.

High Speeds: This came about naturally, but principally for the purpose of reducing the bulk, which was becoming oppressive in direct connected engine units. Fortunately the steam turbine made possible the use of rotational forces not only in the prime mover, but also in the generators, and more recently in the power plant auxiliaries, especially for the boiler and pump rooms. Even the steam velocity in steam piping has increased to unheard of limits. But, this increase in speed went too far. First cavitation developed in the little "Turbinia"; finally appeared the direct current generator, which could not be operated at speeds necessary for direct turbine drive on account of the commutation difficulties with reasonable generator proportions. So the reduction gear came into use, not only in electrical generating apparatus but also in marine work. Metallurgical development has been most striking in the steels and the alloys that go to make up power plant apparatus. Two decades ago the type of steel castings used today was unheard of, and the production of a thin cast envelope of the great size produced today has wrought success out of partial failure of the whole turbine industry. Homogeneous metal in the envelope of the steam turbine is extremely important because of the temperature stresses which occur occasionally, particularly in the rapid starting of the machine under an emergency. Originally that was quite a problem. Later, by carefully designing and mounting the envelope so it would literally hang in mid air and expand both ways, much of the difficulty was avoided. In turbine blade material there has been great progress. One very ingenious combination was a steel core surrounded by a copper protecting skin, and the ease with which that combination metal could be drawn down to the fineness and the accuracy required for a steam turbine blade was certainly remarkable. Had it not been for this metallurgical development it would of course, have been impossible to secure the great peripheral speeds in both the turbines and the generators, on account of the enormous mechanical stresses brought about.

Composite Structure: Another interesting phase was the use of a composite structure in turbines and generators, replacing the old one piece shaft idea of the Corliss engine. In order to secure the homogeneous metal absolutely necessary to avoid dangerous local stresses, the practice of building up the rotor of both generator and turbine in pieces came about, putting them together by shrink fits and various other methods, thus, the rotating part of the turbine became a compound structure. This precaution went so far as to require the main rotating parts to be bored out labor-

iously from a solid steel casting in order to be sure that the interior metal was not "piped," and thus produce unbalancing or serious failures at high speeds.

Direct Connected Units: Of course the old belt transmission, jack shaft and rope drive has been so long discarded that we have forgotten about it. I well remember in 1904 in the then modern public lighting plant, in Detroit, a 500 h. p. marine type engine driving an electrical generator with a rope drive. But the rope broke, and a worse tangle of ropes and machinery you could hardly imagine. Compare this with 50,000 kw. turbine units, and the last large generating units, 47 feet in diameter, that were built in this country for the Manhattan Railways Company in New York. The rotor of these generators was so large that it had to be built up of sheet steel segments riveted together into steel discs carrying the fields and assembled with the aid of a transit. Later, those same units, driven by Corliss engines, two cylinders standing upright and two horizontally (the most compact unit then devised for that power), were connected up at the steam end to a low pressure turbine which utilized the enormous power remaining between atmosphere and vacuum.

Low-pressure Turbine: Here, literally, the tail wags the dog. This is one of the most striking advances made in the whole steam power field; and by the use of the low pressure turbine it was possible to reclaim these old engine plants and actually double their output for practically the same coal consumption. Of course, that type of plant would never be built today, and in this respect the turbine only lent itself for the moment to salvaging the enormous investment in those old plants until their underlying securities could be digested.

Another variety of that type of turbine is the mixed-pressure type, which is capable of running on high pressure, intermediate or low pressure, and which can meet almost any load condition automatically by having steam bled into it at various points in the steam expansion cycle to meet the load conditions that come about. For example, in rolling mills steam hammers and mill engines formerly wasted their exhaust steam, this steam is now taken to a central point and utilized in low pressure turbines. The practice even went so far as to develop thermal accumulators—the mechanical analogy of the electric storage battery. Then regenerators were used to absorb the enormous flunctuations in steam supply and deliver to the steam turbine a continuous flow.

Efficiencies: The greatest advance, of course, has been in the higher efficiencies secured all through the power cycle, reducing losses at every point, from the coal pile to the bus-bar, in the stack, in greatly improved combustion chambers, baffling and tightness of the boiler settings, less radiation from piping, more efficient condensers, reduced iron and copper losses in generators, the power loss due to windage, etc. I understand that the large turbine units of today are able to deliver at maximum load, the most efficient load, a thermal efficiency of about 25 per cent. If we refer

to the old themo-dynamic standard of the Rankine cycle, this efficiency would reach perhaps 75 per cent or more. That is an astonishing achievement in itself. Of course, the Rankine cycle which, as I recall, is based on adiabatic expansion, has its positive limitations, so that when used as a reference, this advance which the steam turbine has made is obvious. In fact, this thermal efficiency is so close to that obtainable from the internal combustion motor which, necessarily, is of the slow-speed type, that the latter has been practically eclipsed. I firmly believe that if the gas engine had had a little earlier start it would have been in the ascendency. Probably the only way it can now reclaim its position is through such research that will develop the gas turbine to a point where rotational effort, with high thermal efficiency, can be brought about. At the present time that does not seem to be available, as no known materials can withstand both stress and temperature.

Condensers: A very large advance has been made in condenser practice. The chief enemy of the high-vacuum condenser is occluded air. Curiously enough, one of the earliest and most authoritative studies made on this subject was by Dr. Smith, a scientist of New Zealand. In that classic paper he developed the laws governing mixed water vapor and air in condenser practice. Today, through the use of various forms of high duty air pumps, most of which are based upon the jet or ejector principle, it is possible to deliver water from a high vacuum condenser at the same temperature as the entering steam, which is quite a feat and would indicate a theoretical efficiency of 100 per cent. Of course, we know that is not quite true. In surface condensers, research has proven the necessity of draining the condenser tubes so as to facilitate fresh steam getting to the tubes promptly in all parts of the condenser.

Heat Principle: Two rather important points have developed in steam apparatus, one the Uni-flow and the other the Counter-flow principle. In a heat engine, the highest efficiency is obtained by the use of the Uni-flow principle, that is, having all metal parts come in contact with the expanding steam or gases, kept as near as possible to the temperature of that steam. A steam engine has been developed on that principle, the Stumpf Engine, built very much like a two cycle gas engine. On the other hand, the highest efficiency in boilers and condensers (heat abstractors) is brought about by the Counter-flow principle, so as to secure the maximum transmission rate of heat from one medium to another.

Simplified Organization: In the working of the plant itself one can't help but notice the extreme advance in the simplicity of the plant organization. It is perhaps like an army. There is the most direct movement from the coal pile to the bus-bar. There is centralized control in a great many respects, particularly at the desk of the load dispatcher, the brigadier general of the staff. He is always promptly informed and can anticipate load troubles, and direct his organization by key board or telephone.

Steam piping has been greatly simplified. Formerly the "du-

plex" system of steam piping was considered to be absolutely necessary for safety. Now that fear has all disappeared and the piping system is as simple, straight and direct as possible. Moreover, everything is tagged, numbered or painted distinctly so that every phase of power plant operation is identified in the simplest possible way.

Remote Control: Remote control and automatic contrivances have reached an extraordinary stage. For instance, the turbine governor is in absolute control of the load dispatcher at the switch board rather than by the engineman. Then there are emergency valves, reverse check valves, time-limit circuit breakers, speed-limits, all doing the work which the original power plant operators had to do themselves. They are so interlocked and related that almost every avenue of disturbance in the power plant is barricaded to the common enemy—"Trouble."

Records: In the matter of records and instruments we have today instruments undreamed of even twenty years ago. Thus, for example, the ingenious integrating steam-flow meter. Then we have CO_2 recorders, to determine efficiency of boilers, engine and combustion. Also every kind of indicating, recording, integrating and printing instrument to facilitate accurate registration of facts, various feed water measuring devices, controls by temperature differentials and instruments for ascertaining the temperature of the interior windings of generators by resistance. One wonders how, in the early days, a power business could be conducted on a commercial scale without such systematic records.

Cost of Plant: In attaining higher commercial efficiency great reduction has been made in the cost of the entire plant. Twenty years ago, $150 per kilowatt was generally the rule for high-grade plants. Today, the increase in size and concentration of units has brought the cost down, until $70 per kilowatt is not unusual and even that has been reduced. The use of the steam turbine has permitted "double-deck" stations in some cases, where the site permitted, with boilers below and turbines above. Labor saving devices and mechanical and automatic methods with the use of lower grades of coal have all combined to increase very greatly the over-all commercial efficiency of the plant, and enable power to be sold at extremely low figures from ½ to ¾ cents per kwt., depending on the load factor.

Depreciation: Depreciation and amortization have been talked about for years as factors in power costs, yet without engineers and laymen coming to an agreement. I don't think they are in agreement today. Yet in this very field of power plant engineering where could we find a better example of the absolute necessity of anticipating the future and providing for depreciation that is taking place. Some time ago, I was told by a prominent New York engineer that his board of directors absolutely refused to let him shut down a big but inefficient New York power plant because there were mortgage bonds outstanding upon it. Yet he could have scrapped the plant, used power from a turbine plant

and been money ahead, amortizing the old plant in perhaps five years. In Detroit turbines of several thousand kilowatt capacity have been replaced and paid for in a very short time by more efficient ones. Here is one of the best exmples of what the great development in steam power plants has shown us.

Research: A better view of the great underlying principle of economics through all this absorbing story of achievement runs the golden thread of intensive research and discovery by an army of engineers, known and unknown. The commercial horizon of power development has been enlarged a hundred or perhaps a thousand times and mankind benefitted accordingly, though he is still a grumbler, sometimes, over rates. But I cannot over emphasize the value of research in this whole program, because success has come only through research, and some of it has been painful and expensive research as the sombre junk-piles back of our factories mutely testify. We would never have had one fraction of the advance enjoyed today except for the millions that have been put into the research that has produced these high efficiencies, these alloys of such wonderful strength and these refined methods of automatic control.

In conclusion, I think that research should continue to have the support of the whole engineering fraternity. It is perhaps our proudest achievement of the past. And, in this coming intense era of competition (of brains rather than brawn) it may become the most important foundation-stone for future American progress.

Outline of the Most Striking Developments in Telephony During the Past Fifty Years

History of the Art, from Its Beginning as a Scientific Toy to an Industsy of Thirteen Million Telephone Stations, Spans Scarcely Half a Century

By Frank F. Fowle, M. W. S. E.

IN the limited time at my disposal it is possible merely to sketch the briefest outline of the striking developments in telephony during fifty years of progress. In fact the history of the whole art, from its beginning as a scientific toy down to the great industry of some thirteen million telephone stations today, scarcely as yet spans a full half century. Thus, fifty years of progress constitutes in this case the entire story of an art. The early history of telephony and the manner in which the industry came to be organized are probably unique. Mr. Bell's invention comprised essentially the telephone receiver, in but slightly different form from which we know it today. His patents, however, covered broadly the transmission of speech by electrical means, as well as the apparatus itself, and for this reason the Bell Company attained a commercial monopoly during the life of the fundamental patents and thus reached its impregnable position in the industry. The Bell instrument was originally used both as a transmitter and receiver, but it was not efficient as a transmitting device and this led to efforts to find a more efficient substitute, which soon resulted in the discovery and improvement by Edison, Hughes, Blake, Berliner, White and others of the microphone or carbon transmitter.

The Bell system has developed as an organization along practically the same lines as were conceived by its founders, comprising a central or holding company which owned the patents and established the standards and fixed the policies of the operating subsidiary companies. These subsidiaries, of which there are now about forty, were granted perpetual licenses by the parent company to conduct a telephone business in respective districts, so arranged as to cover the whole country. The parent company also organized a manufacturing subsidiary to build telephone equipment and purchase supplies for the operating subsidiaries.

Before the fundamental Bell patents expired, however, in 1893 and 1894, the telephone business grew with such strides that the financial capacity of the Bell Company was unequal to keeping up with the demand, and as soon as the field was open the independent or competitive era in telephony was launched with great vigor, commencing about 1895. The competitive period passed its zenith some few years ago, however, and today the tendency is decidedly toward local monopoly of the business under public regulation. At one time, shortly before the Great War, there was a very marked drift toward a national monopoly of the entire industry by the Bell system, but steps taken by the Government brought this to a halt

and today the elimination of local competition is proceeding by piecemeal interchanges of properties and by a process of purchase and sale which aims to preserve the status quo as regards the relative ownership by Bell and independent interests.

It is of passing interest to recall that hard-drawn copper wire, so widely used and needed today, became a necessity in the telephone industry and was invented by Doolittle in the early eighties. Soon after that came the idea of the multiple switchboard, which in the modern manual system is the fundamental feature of every central-office equipment in practically every city in the country. At about the same time the evolution of the paper-insulated lead-covered cable commenced and improvements have continued from time to time down to the present day, until it has become feasible to place no less than 1200 separate pairs of wires within a single sheath and in a single duct of underground conduit. These latter developments are largely responsible for the extended underground systems of distribution now so common in every city of substantial size.

Simultaneous telephony and telegraphy was invented by Van Rysselberghe, a Belgian, who came to this country in the eighties and demonstrated his system. It was perfected and placed in practical operation by the Bell Company on the long-distance lines as early as 1895, and today it is very extensively used in a modified and improved form. The year 1896 or thereabouts was marked by the introduction of the common-battery system, which has since displaced the early magneto system almost universally except for small exchanges in rural districts. In 1899 Dr. Pupin announced his epochal invention of the loading coil, which took inspiration from the classical researches of Heaviside, and at once gave tremendous impetus to the art of long-distance telephony. Shortly afterward Shreeve developed his electro-mechanical type of telephone repeater, which, though not an ideal device, was a distinct achievement.

The last striking development in the transmission art is the vacuum or audion type of repeater which was discovered by Dr. De-Forrest, and with which the Bell engineers made transcontinental telephony a reality. This discovery and its reduction to practical use constitute one of the outstanding achievements in the history of the art and the future effect of it in opening the way for improvements in the type of transmission plant seems certain to be of great importance.

The art of automatic telephony was developed by the Independents, among whom Strowger was one of the first to perfect a complete and practicable system, which has come into very extensive use among independent companies. The Bell interests from the first championed the manual system, while the automatic was sponsored by the independents, but the unprecedented economic situation produced by the Great War has now brought telephone engineers to the nearly unanimous conclusion that the automatic system is now an economic necessity and within the next decade

we may look for rapid conversion of manual installations to automatic, as rapidly, in fact, as the operating companies can digest the program from a financial standpoint.

The latest interesting development is the tendency toward further elimination of the open-wire plant for toll and long-distance service, in consequence of the application of the vacuum repeater and the further perfection of the art of loading. This means that all-cable circuits, either underground or aerial, will continuously replace open-wire construction. Where the large number of circuits or the importance of the route will justify it, underground construction will be the rule, but if not, the construction will be aerial cable supported on a pole line of low height and rugged construction to avoid storm interruptions and destruction. The very long lines will probably constitute an exception to this tendency, however.

These are the outstanding milestones of progress in the telephone art, as seen from a very hasty review of its history, but it has been possible to speak of them scarcely more than by mention and in such a rapid survey of a great art it is inevitable that many interesting and important facts have been passed over.

Reminiscences of Past Presidents

Personal Views and History of Some of the Men Who Are Responsible for the Growth of the Society

THE Society was fortunate in having among its members who participated in the fiftieth anniversary celebration a large number of its past presidents. All our living past presidents could not be present, but those that were gave ample testimony as to the growth of the Society and the honor they felt at being elected to fill the highest office in the gift of their fellow members. Following are abstracts of their remarks:

John F. Wallace, M. W. S. E.: I am very glad to be with you, very glad to see you and I hope that I can make my remarks brief enough so you will be glad to see me. I first came to Chicago in 1856 and I can barely remember passing in over a tresle on Lake Michigan. I took my first job as a rodman on a branch of the C. B. & Q. in the autumn of 1869. After I had worked about three months my chief said my services were not needed any longer. I asked him for a letter of recommendation and he gave me one. This is what it said: "Jordan Wallace has worked for me for three months and I am satisfied." I have had one particular experience with the society, and I think I am the only man that had that experience. I ran for president of the Western Society of Engineers twice and was elected once. When we start out in life we have a great many ambitions, but as the years go by we see those ambitions gratified, or we outgrow them, or we become philosophers enough to see them go unrealized. Today, as I stand before you I only have two ambitions left in life; one is to make a record of living fifty years of the same life; the other is to see the lake front ordinance passed within the next few weeks.

Ralph Modjeski, M. W. S. E.: I came to the city in 1892 and immediately joined the Western Society. I was fortunate enough to be elected in a few weeks. I came to my first meeting and saw the gentleman in the chair, and I wanted to get that honor of taking the chair in the future years. Isham Randolph looked then about forty and he looks now about forty-one. About eleven years later I had the great honor of becoming president of this Society. I have also the great honor to be here tonight at its fiftieth anniversary. I hope that nine-tenths of us, at least, will attend the one hundreth anniversary fifty years hence.

C. F. Loweth, M. W. S. E.: This has been a day for reminiscences, and I am very sorry that one of our past presidents, whom we all love, could not be present. I would like to have heard him. I am reminded of a little reminiscence that he told once, and the story runs somewhat like this: Back in the seventies (I don't think it was any earlier than that, although it may have been in the sixties), the city of Cincinnati was building a very notable piece of railroad construction. It was notable because it had notable engineers

managing it and it was truly a notable piece of work. The bridges were very fine and were being designed by a young man just out of the university, and his name was Stroebel,—I think they called him Charles. About that time another young man came to Cincinnati from Missouri in search of a job. He had, I think, served an apprenticeship in an iron foundry. This young fellow's name was Bates, and he got a job on the Cincinnati Southern Railway. He was a draftsman. We listened this afternoon to the list of the early founders of this Society and amongst others was mentioned the name of a man whom I never met but twice, and I honor and cherish his memory. His name was Chesbrough and he was a very distinguished city engineer of Chicago. You will pardon me for personal references in bringing out the tribute that I want to pay to Mr. Chesbrough. He was not only an engineer of a very high order, a distinguished and notable engineer, but he was a gentleman of the finest mould. It was that phase of that man's character that, more than anything else, recalled him to my mind and my heart. It so happened that after I had been at work in Chicago for six months I found myself one day out of a job, and I walked back and forth through the city trying to find something to do. I had the notion that perhaps it wasn't worth while for me to go over to the City Hall and see the city engineer. I assumed that nobody could get anything in the City Hall unless they had some pull somewhere. But I decided to go to see the city engineer. I don't know how I got into Mr. Chesbrough's office, but I did it somehow. He said, "It is a pretty bad time, the first of December, to be out of a job." His organization was full and he didn't have any place to send me. Then an inspiration seemed to come to him and he said, "I have a friend coming to my house. He will be there for dinner Thursday night and if you will come around Friday morning it may be that he will know of something, because I think he may be interested in some engineering work that is coming along." It seemed to me that it was too good to be true to think that he would remember me the next night. However, I went around Friday morning to see him. As I stepped into his office he was writing a letter. He said, "Just a minute and I'll see you." After he had finished his letter he felt in his vest pocket and he said, "My friend was at my house and I spoke to him about you. He gave me this address and he said that he thinks you will be able to get something to do." Mr. Chesbrough gave me the address with a great deal of pains and told me that it was the first stairway from a certain corner and on the second floor, and after I got to the top of the stairway it was the second door on the right hand side. I went there and I was engaged to be down the next day as a rodman for the Wabash Railroad. I feel, and I have felt all my life, as if I could not pay that obligation to Mr. Chesbrough, but it was an obligation that I had to pass along to those I came in contact with, so I have honored his memory and cherished it as one of the abiding satisfactions of my life.

I was very much interested this afternoon in listening to the

remarks about the progress of the last fifty years. It is truly wonderful the progress that has been made in the past thirty years, and I firmly believe that that progress in a large measure has been due to the activities of engineering societies. I believe that to the extent you and I, as members of the engineering societies, have contributed of our time and our mind and our efforts to further the work of the society, we have, in some measure, been responsible for the wonderful progress that has been made during the last fifty years. I believe in the engineering society because it keeps a man in touch with the engineering activities. I believe in it for the older men because of the accomplishments of the service.

Andrews Allen, M. W. S. E.: We had a meeting of the past presidents ten years ago. It was a meeting very much like this one tonight only we did not have so many of them here. At that time we had very interesting talks from many of them. It is a splendid idea to bring them back once in a while to devote a meeting to, you might say, reminiscences, and the history of the society. But this society stands at the parting of the ways. Every day is the division between the past and the future. We are planning big things here now. We are planning larger powers to our organization; planning a little freer field of action so we can enter into our public duties more completely than ever before, and we must look forward to these things, and not backwards. This week brought out one thing which probably most of you know about, that is, the revised engineers' license law has been passed and signed by the governor. After so many wears of struggle, we have at last attained a thing that engineers are entitled to, that is, the right to bid on what his ability enabled him to bid, without working under an architect or being hampered by regulations which are not right or proper.

The architects, as you know, had the structural business pretty well tied up. An engineer went in by their favor when he went into building construction. Now the engineer can stand on his own feet. We had a law passed about four years ago. The last law has removed the limitations of the old law and the engineer now stands where he belongs.

John W. Alvord, M. W. S. E.: The most interesting reminiscence which I can think of is to describe to you the first meeting of the Western Society that I attended. As has been said, I joined the Society in October of 1885. I was then an engineer of Lake View. My bailiwick extended from Fullerton north to Ridge Avenue and from Western Avenue east to the lake. There were about 1800 people up there at that time. After being admitted to the Society I concluded that I would come down and see what a Western Society meeting looked like. My diary says that the night I came down it was registering 19 degrees below zero. We had to come down in a horse car at that time. The Society met in a very large room full of exhibits of structural materials, and it occupied one remote corner with about two or three gas

jets in this very large room. The late Benzette Williams was president and he was there, and our honored secretary, L. B. Morehouse, was there also. I don't recall whether there were two or three other members present, but there were not more than that, and a considerable portion of the time was consumed in reading the minutes of the last meeting, which were finally approved. Some little discussion was had as to how to increase the membership and the meeting was adjourned. I betook myself to the horse car again and in the 19 degrees below zero plodded home. I didn't come down to a Western Society meeting for some years before that and I didn't find my voice registered in the Western Society for some years after that.

But the thought that came to me is that in all those early days someone had to carry on the work of this society, and there were wheel horses in those days that were resolute enough and persistent enough and far sighted enough to keep this association going even if they didn't have much of anything to do but to read and approve the minutes of the past meeting.

Albert Reichmann, M. W. S. E.: I was very much interested today in the talk on the development of the society and there were some remarks made that the society hadn't grown very much in recent years. I can attribute that to one cause, and that is this, that the first twenty-five years of the growth of this society we were busy building our large railroads and in the last twenty-five years our country has been devoted more to industrial development, and there have been a great many organizations formed for doing special work. Take, for instance, in the line of furnishing materials, we have certain organizations that are run, you might say, in the manufacturing interests. We have the American Iron and Steel Institute, which devotes its attention to the production of steel, and it is a big problem. On the other hand we have such organizations as the American Society for Testing Materials, which is composed of both the producer and the consumer, and we have such organizations as the American Railway Engineering Association, which devotes its attention to the side of the consumer. One is the organization of the manufacturers, the other is the joint organization of the manufacturer and consumer and the third the organization of the consumer. What we want to do in Chicago is to make this a headquarters for all of these various branches of the engineering profession, and it may be necessary to divide it into chapters and give these different organizations an opportunity of meeting, and it will give us an opportunity of getting acquainted with all the different people that are allied in the different industries. That also applies, you might say, to our work, which is structural work. We built power houses, mining structures, etc. A few years ago they used to put up a couple of buildings to extract copper and grind the ore down and refine it. But since then it has become a very intricate problem. The copper producing plants have become very intricate; the construction has become quite a feature. The same thing is true of electrical development. We have a great many

organizations that take the different phases of the different kinds of engineering. If we could just get together and get these various organizations centered in Chicago, because Chicago is a wonderful engineering field, I believe that in another twenty-five years Chicago will outclass every other city in the world for engineers. We have all the things necessary for industry in this community; we are in the heart of the greatest agricultural district in the world, and I can see only a great and glorious future for the society if we get together and organize and make it the right kind of a society.

H. J. Burt, M. W. S. E.: I arrived on this lively world a little too late to be a founder member of this Society and I really feel I am one of its younger children. When I was made your president, I was accused by one of the old "wheel horses," a past president, of being a very young member to be so honored. This charge was true, and I received the honor with trepidation and due humility.

That year, 1917, the forty-eighth year of this organization and the forty-fourth year of my own existence, will be a memorable one to me. That memory will always be a keen sense of the high honor of being selected to this high office of trust and responsibility; great satisfaction because of the progress and work of the Society during that year; an unbounded appreciation of the kindly courtesy and coöperation of the members and officials of the Society; and a deep regret that circumstances and my own limitations prevented me from accomplishing the full measure of successful administration that should have been attained.

The year was not an epoch marking period; there was no notable achievement. It was, however, a critical time, a time when the Society might easily have begun to fall into decay. It was burdened with a considerable dead wood in its branches and dry rot in its trunk. These defects were pruned and cut away. It required hard and steady work by the officials and committeemen, which was unknown to the membership at large, and, consequently, could not be appreciated by them. However, there is a bright item in that year in the securing of Mr. Nethercut as secretary, which I consider a great good fortune.

The year, 1917, is too recent to be of much value or interest in retrospect and I prefer to look into the future rather than into the past,—to dream of the great opportunities rather than to contemplate the things already accomplished. It requires only a casual acquaintance with engineering affairs and a few minutes' reflection to conjure visions of great things in store.

I foresee a great increase in membership. It may come about through absorption of the other engineering societies of Chicago into this body. Such a procedure might reasonably occur. The policy of the Western Society of Engineers is broad enough and its form of organization elastic enough to permit it. Whether the increase comes about in this way or by natural accretion, the material is available for a large multiplication in our numbers.

I hope to see the time when the privilege of membership will mean the privilege of coöperative work. When everyone who wears our badge will contribute some effort toward the advancement of technical knowledge or practice, to the betterment of public affairs in engineering matters or to the improvement of the condition of his professional brothers. As at present operated, about five per cent of the members do the real work of the Society. Perhaps twenty per cent avail themselves of the privilege of attending meetings.

If the Society can be successful on such a low basis of efficiency, what a tremendous performance it can make if all members work. I have not yet found a member of the Society who was not willing to do any task assigned to him, so I believe every member is a potential worker, ready to come into action at the call of officials or committee chairmen. To avail ourselves of this force will require leadership and organization to bring it into activity.

In preparation of my annual address, as president of the Society, I worked out a scheme which I did not submit, because of the over-shadowing interest and importance of our war problems; a scheme whereby this potential energy would be used in a complete revision of existing engineering literature and its extension to keep it abreast of engineering practice. It could direct the correlate experiments in engineering matters and put the conclusions in shape for practical use.

It needs only a cursory examination of our engineering literature to show how fruitful a field this would be. There is a certain percentage of that literature which is obsolete and otherwise useless. Another percentage is duplicate, and another portion unavailable, because not well known or buried in useless chaff. This would indeed be an ambitious undertaking, but not impossible, and it carried through would make this the greatest engineering Society of the world.

There is room for energetic activity in public affairs. Our committees can with propriety participate in the discussions and help formulate public opinion on the great public works. In the execution of public works the Society might well nominate the engineering commissions to be appointed and employed by the public authorities for conducting these enterprises.

It seems clear to me that no extended argument is needed to show the great possibility for future development, and I hope I may have a part in making these possibilities into realities.

Charles B. Burdick, M. W. S. E.: It has been a great deal of value to me to attend this congress of past presidents today, and I have been delighted to listen to the story of the Western Society. I wish I could add something of value, but as my term ended only last January I find that difficult. You can't reminisce about the things that happened yesterday. We like to hear about the older things, half forgotten things, and then again, as Mark Twain says, "There is no use to spoil a good story by sticking too closely to facts," and as he further says, "The longer I live and the older I

get, the better I can remember the things that happened in the days of my youth, and now I have reached a point where I can begin to remember the things that never happened at all." But I can't follow the advice he laid down, for the happenings of my term are so recent and you are so well acquainted with them that you would cry for me to stop. Therefore, I will be content to let the story end with the presidential terms sufficiently remote to be clouded in the haze of distance,—not that I think that the previous speakers, our past presidents, have been following Mark Twain, for I believe every word that has been said.

Isham Randolph, M. W. S. E.: Fifty years, half a century, has been the span of life of the Western Society of Engineers and yet it is younger by eight months than my professional career; provided you admit that a man's engineering career can begin when he makes stakes and drags a chain, for thus did I begin.

It began in the old valleys of Virginia, on fields on which the scars of battle were still visible, fields on which Americans fought each other and fattened the soil with brothers' blood. What prompted such a beginning? Poverty was the prompter. The gates of knowledge are "buried in the gold and open but to golden keys," nevertheless yield up their treasures to him who toils for them and seeks them with hunger of soul. I hungered and I toiled. What my reward has been most of you know.

The years since 1868 have been the most wonderful years in all of the world's history. Science has opened many doors and brought forth treasurers hidden behind them "since the morning stars first sang together and all the Sons of God rejoiced." At the beginning of this fifty-year period electrical science had made little progress beyond the stage to which Morse brought it. The telephone was an interesting experiment, and Bell and Gray were training the toy to become one of the most useful servants man has ever known. Westinghouse increased the speedy operation of railroads by applying the air brakes. Combustion engines have been brought to perfection and their power applied to the automobile, the motor boat, the heavy truck and to countless other users of power. The bicycle appeared as a recreative mode of transportation and it has been demonstrated as a useful errand runner and swift messenger.

Electricity is yet a mystery, but man has harnassed it and it does his bidding; flowing through wires, as water through pipes, to be turned on or off at will; becoming light by night and power by day or night, driving machinery small and great; vieing with steam in propelling railway trains, and surpassing steam in that it may be stored and tapped for service as wanted. The Wizard of Melno Park has wrought many wonders, none greater than capturing sound and canning it for use as wanted. The eloquence of the orator, the actor's voice and intonations, all these, captured today, may sing and speak again a hundred years after they who sang or uttered them have returned to the dust from which man sprang.

Nor is this all. The photographer has captured the faces, expressions, forms, actions of these prima donnas, orators, actors and these will give to generations yet unknown a perfect visual presentation of the originals. And so, by synchronizing voice and action they may be seen and heard a hundred years hence. The blue vault of heaven is no longer the exclusive domain of the birds of the air, for today bird-men, singly or in flocks, soar aloft and to heights which eagles even never mounted.

This triumph of science man has aspired to for ages, but victory has not crossed his efforts until within the last two decades. Much of that victory was predicted upon the research and experiments of one of our presidents who has gone to his honored rest. Octave Chanute, whose gliding experiments, prosecuted among the sand dunes of Northern Indiana, demonstrated underlying principles which have made aerial navigation possible. The last time that I recall seeing and hearing him speak was when he talked to this society about his gliding experiments. He said that he would never live to see the outcome of his work, but that he had demonstrated the principles which would make the flying machine practicable. Wilbur and Orvil Wright followed the path which Chanute outlined and now men have crossed the Atlantic in a flying machine. Within this span of fifty years the transcontinental railways have been built, so has the Brooklyn Bridge and many others its near equals, if not its superiors. Eads built the jetties and the St. Louis bridge. The New York subways have been built and its wonderful water supply. The Chicago Sanitary and Ship Canal has been built only to be eclipsed by the Panama Canal. Submarines have been brought to perfection and have won the damnable distinction of being the "assassins of the sea." Chemistry has made wonderful strides along the ways of peace and the paths of war. Diabolic science has devised wholesale means of slaughter and consecrated science has revealed new and merciful ways of healing.

Man has sought out so many inventions during these fifty years that it takes volume after volume to preserve the record of them. So much for the high spots of our advancement. But other history has been made. America can no longer stand aloof from the nations of the earth, for good, we believe, we are a world power. Within this fifty years we have liberated Cuba and broken the power of Spain. That was a war which cemented the union of the states. Then the sons of the South rallied to the flag against which their fathers fought and many of those fathers grasped the hands and marched in rank with the veterans whom they had faced on many a contested field. And again, old world civilization was in peril and its hard pressed defenders called for help and America gave it—gave it in millions of men, and billions of money; and the gift was effectual, for because of it the veteran armies of the Kaiser—the would-be world conquerer—succumbed and Germany sued for peace, and took such a peace as the alien powers prescribed. Fifty momentous wonderful years have passed into history.

Engineering Developments in Chicago During the Past Fifty Years

The City's Growth from an Unpaved, Unlighted Country Village to a World Metropolis a Miracle of Progress

By Samuel Artingstall, *Past President,* W. S. E.

THIS evening we have come to celebrate the Fiftieth Anniversary of this Society. It may be of interest to know that I arrived in Chicago on May 1, 1869, and within an hour got a job in the engineering department of the city, and stayed on the job for 26 years, the last 11 years being city engineer. I will give some scattering and disconnected facts about the engineering work in the city during that period.

I came into the city on the Illinois Central Railroad, which entered the city from Park Row to Randolph on a pile track built in the lake at its present location. Michigan Avenue was the shore of Lake Michigan, and during storms the roadbed of the street was flooded and often damaged, and sometimes very seriously. Michigan Avenue was an exclusive residence street, where many influential and wealthy citizens resided. The Blackstone Hotel is built on the site of the residence of the late Timothy Blackstone, then president of the Chicago and Alton Railroad.

On the north side, the lake seemed to vent its spite or ill will, for at every storm the roadbed of Pine Street, a short distance north of the water works intake (the protection of which extended quite a distance into the lake) was regularly washed away. From about one-half mile north of Division Street to North Avenue was the Catholic Cemetery; at North Avenue was the Public Cemetery, which ended at Center Street, where Lincoln Park commenced. The park extended to Fullerton Avenue. The western boundary of the cemeteries was State Street, and of the park, North Clark Street. After the fire in 1871 the bodies were removed, and that portion above North Avenue added to the park.

Fifty years ago only the important or busiest streets were paved or improved. The pavement was white cedar blocks on plank foundation. This pavement received no care after being laid, and soon after a severe rainfall, when the streets were flooded, you could find the blocks anywhere but where they should be—the street being full of holes and bumps. One fixed landmark was on Randolph Street opposite the Sherman House, where for years a barrel was fixed and anchored in the middle of the roadbed with a large sign "No Bottom," as a warning to teamsters.

Soon after my arrival in the city I naturally wanted to see the surrounding country, so I boarded a State Street car at Madison Street. This car would hold about twelve passengers. You entered the car at the rear, walked to the front to deposit your fare—if you did not the driver would stop the car and fetch you. The car

was dragged along by a rawboned mule as far south as Twelfth Street, the southern limit of the street car line.

The track was a strap rail spiked to stringers (no ties) held at proper distance apart by one-half inch rods placed at suitable distance apart. The pavement between the tracks was cobble stone. The sidewalks were all of wood, not built to any grade, every property owner building at a level to suit his own convenience and building, so in traveling a block you had to ascend and descend the stairs to the different levels several times before arriving at the next corner. After the fire in 1871 the city raised the grade of the streets from 12 to 14 feet above low water of the lake; passed a fire ordinance prohibiting within certain limited area the building of wooden sidewalks and buildings. An ordinance was also in existence, fixing the width of roadway and sidewalks, for 66-ft. streets (which is the general width of street in the city)—roadway 38 feet wide, sidewalks 14 feet wide. These regulations were adopted at the time of mud roads or no roads at all by the engineers of 50 years ago. You engineers have faithfully lived up to the old rules. Cannot you make an improvement and build the streets suitable for the use they will be put to? Why follow the same width of roadway and sidewalk in the loop, whose every street is crowded with street cars, wagons, autos and elevated roads and, including the sidewalk, every available space crowded. In the streets devoted to manufacturing, warehouses, and similar uses, where the roadway is devoted to heavy traffic but limited on the sidewalk; on outlying business streets, where in some cases the sidewalks are crowded and not much traffic on the road; on strictly residence streets, and on streets devoted to small cottages and bungalows you find the same inflexible width.

Cannot the engineers of the present time work out a more flexible set of regulations that can be adapted to meet the uses the streets will be put to? I think they can. As an instance let me call your attention to a residence street built up with small and medium size dwellings, such streets where the majority of our fellow citizens dwell, where the only use the roadway is put to is the daily milk and grocery wagons, and an occasional load of coal—is it necessary to pave with asphalt at something over $3 per square yard a road 38 or 48 feet wide? Would not 20 or 24 feet be wide enough and to spare? With the six-feet foot paths you could add 9 and 12 feet on each side of the street to be devoted to grass, shrubbery, trees, and reduce the cost one-half by not building the useless part of the roadbed, which has already cost many million dollars and will cost many more to keep in repair, sprinkle, clean and maintain. You avoid by one-half the dust and dirt from being blown in the residences and on the food and furniture. You provide a more healthful, beautiful and pleasing street. With the increased space you might with advantage forget straight lines, let the trees get unruly and stagger around a little in the limited space they have. If they forget to stay at regular and stated distance apart

so much the better. Also there are many fine trees besides Carolina poplar which will grow in cities—how would it look to intersperse a few of them occasionally, to break the monotony? In my opinion the rules in the ordinance mentioned could be improved and made so that it provides for the building of such streets, and for the most densely crowded traffic and for conditions between the two—the actions of the engineer have great weight in such matters.

Fifty years ago the city obtained its water from the lake through a wooden trough that led to the shore of the lake and from there to the pump wells at Chicago Avenue and Pine Street. Water was delivered to the pump wells through a wooden trough—a protection of open pile work commencing at Pearson (the north side of the water works property), going eastward a few hundred feet, thence by a semicircular curve ending at Chicago Avenue, the southern limit of the water work property. This formed a pool of water inside the protection but open to the passage of lake water through the spaces between the piles. In this pool the wood trough ended, and to keep it open and free of ice in winter the condensing waters and exhaust steam from the engines was used.

At this time all sewers on the south side and east of State and south of Randolph streets discharged their sewage into the lake. All sewers north of Grand Avenue, I think, and east of Clark Street (including connections) discharged their sewage on the lake shore. All other sewers in the city emptied into the Chicago river and its branches, and the river was a cess-pool of sluggish current except during flood, discharging this sewage into the lake a little over one-half mile south of the water works intake. When the south wind blew the people got the south side and river sewage; if the north wind blew it blew the north side and cemetery sewage; while the east wind blew a combination. During flood times the deposits on the bottom were stirred up. The accumulation at the stockyards, the river and its branches, ships, all the ditches and pools in the watershed poured their filth through the Chicago River into the lake in the vicinity of the intake from which the people got their drinking water. With such conditions it is no wonder the inhabitants made constant and vigorous protest, which resulted in the construction of a water tunnel five feet in internal diameter with the intake directly east of North Avenue and 10,000 feet from the shore, the western end being at Chicago Avenue pumping station and thence delivered through the mains to the water takers. This important event, the opening of the five-foot tunnel and taking of the drinking water two miles from shore occurred just fifty years ago, in 1869.

There was much rejoicing over the event but they soon found that this work was not wholly perfect. Under favorable conditions of the winds and waves some part of the sewage reached the intake. Every winter, without an exception, the water supply was endangered and often stopped by anchor ice at the crib. At this place as many men as could be accumulated on the structure worked in

relays 24 hours per day, doing their best to remove the accumulating and increasing obstruction of anchor ice which, with all their effort, sometimes failed. I do not remember of a single winter when the supply was not shut off at the crib and the supply taken through the wooden conduit from shore. The formation of anchor ice required favorable atmospheric conditions, especially on calm days, and still waters came suddenly and without warning, lasting from a few hours at times to a few days. As to the cause of this ice formation I will give my views a little later on. The supply of water through this five-foot tunnel was not sufficient and could not supply the demand, and the capacity of the conduit was too small, so an additional tunnel seven feet in diameter was built from the same intake parallel to and fifty feet distant from the first tunnel to the Chicago Avenue works, from there it continued in a southwest direction to a new pumping station at Ashland Avenue and Twenty-second street. This was completed and put in service in 1876.

The demand for more water still persisted and a new tunnel eight feet in diameter was started from the foot of Fourteenth Street, but difficulties were encountered—unfavorable ground and fine silt. After going some distance under the lake two tunnels, equaling the capacity to the eight-foot tunnel, were substituted and so continued until they met the eight-foot, which was under construction from the new intake where they are joined together. This crib or intake is located four miles from the then shore where the water is 40 feet deep; at the first or two mile crib the depth of the water is 18 feet. There has been no trouble from anchor ice at the four-mile crib. This I attribute to two main causes. From investigation and observation at the two-mile crib we found that the presence, in the ports or intakes, of any iron, even as small as a nail head, was nucleus on which this formation occurred, and in moving waters it formed with astonishing rapidity and the accumulation carried by the flow. We found also the small pebbles on the lake bottom where the ice was formed but not to a serious extent. When the four-mile crib was built no iron was used within six inches of contact with water, from the bottom of the crib to several feet above the ports or opening for the passage of water. The linings of the ports are wood six inches thick secured to the solid wood work and securely fixed in grooves and dovetailed without rail or spike, giving 12 inches in these places between any iron and the moving water.

Whether anchor ice will form on metal and pebbles at a depth of 40 feet I am not able to state, certainly there has been no trouble at the four-mile crib. At this point I wish to correct a mistake made in a paper read before this Society sometime ago by Colonel Allen, in which it is stated that this timber part of the crib was used to lighten the structure, to assist in floating it from shoal water to the site. This is a mistake; its use for this object was never thought of; we had more flotation capacity than we needed and

NOTE: Water was delivered from the 4 mile crib early in 1893.

plenty to spare. The lower part of the work is built with three courses of 12x12 inch timbers, layed close together, each course at right angles to the course below and secured to it by ⅞x2 feet drift pins. Above this floor and on it was built the outside walls of the structure of solid 12 in. x 12 in. timbers in courses at right angles to each other. This particular part of the structure extended (if I remember correctly) three feet above the top of the port opening. The openings themselves are 5 feet high by 4 feet wide, the bottom being the top of the first three courses of 12-inch timbers. This left an interior well 70 feet in diameter. Before launching the structure all parts were closed by bulkheads and made water tight, leaving the interior well dry. As the floor of this was only three feet thick and must withstand an upward pressure of 40 feet of water, it was held down by a number of inverted Howe trusses. The rods were so constructed that they were easily detached from the bottom. Forty feet of water has an upward pressure of 2,500 pounds per square foot and this multiplied by the area with a 70 foot diameter gave all the floating power we needed and plenty to spare.

Cribs or intakes with connecting and pumping stations have since been built at Hyde Park, Lake View and other places.

The agitation for pure water continued unabated and resulted in the appointing of a commission to investigate and recommend the best method for the disposal of sewage of the Chicago River, prevention of floods, and to prevent the pollution of the water supply. This commission consisted of Rudolph Herring, chairman, the late Benezette Williams (past president of this Society) and the speaker. This body recommended the building of a system of intercepting sewers both within and far beyond the city limits, the reversal of flow of the Chicago River through the Desplaines Valley, the Illinois River to the Mississippi River. This recommendation of the commission was accepted, suitable acts for its accomplishment were obtained from the state legislature and resulted in the creation of the sanitary district, the building of intercepting sewers and the building of the drainage canal with a capacity of 600,000 cubic feet of water per minute from the city to Joliet, forty miles to the Illinois River. These works have been completed and the sanitary district is now engaged in reversing the flow of the Calumet River, which still empties its water and sewage from the great manufacturing district into the lake.

I will mention only one great flood which caused injury and damage to property and pollution of the lake waters. These floods occurred at least twice a year, their severity depending upon the rainfall, melting of the snow, the area of the water shed and other causes. The main source of floods in Chicago was the overflow of the Desplaines River. To limit this a dam was built on the east bank of the river near Summit, 12 miles west from here. Vigorous protests were made by the people and authorities of Joliet, Lamont, and all other towns, villages and farms in the Desplaines Valley. There is a fall of 40 feet from the surface of the water at Summit

and the surface of the water at Joliet. The crest of this dam was finally agreed upon and fixed at 12 feet above the level of the streets of this city, and located twelve miles southeast from here.

The Desplaines River above Summit flows in practically a north and south direction. At Summit it takes a sharp bend and goes in a southeast direction. If you will kindly bear this fact in mind, you will appreciate the dangers of a flood. The speaker had charge of the care, repairs and maintenance of this dam. The Herring Commission, for its information and use, established gauges to record the height of water in the river. These gauges were fixed at suitable intervals from the source of the river in Wisconsin to Joliet, and also on the main branch. They numbered several hundred. They were read twice a day, the observers being intelligent persons living in the vicinity. The readings were entered on post cards on a suitable printed form, the observer having but to fill in the height of his particular gauge. The late Lyman E. Cooley, one of your past presidents, then in the employ of the commission, had direct charge of this work.

Usually the flood in the lower reaches of the river have passed their maximum and gone before that from the upper area to its source arrives, and the waters pass away gradually with a minimum of injury. Unfortunately at the time the opposite was the case. An unusual and heavy fall of unmelted snow lay on the ground over the whole watershed; the tributaries were frozen over, and with Spring came sudden continuous warm weather; heavy rains commenced in Wisconsin, the snow and ice melted and the flood started. Gradually and quickly it advanced, increasing in volume as it came. The snow and ice and the winter's accumulation of water were melting and would soon give up and add their stores. Salt Creek, near Riverside, was started and added a great volume —in fact the drainage of the whole watershed arrived at one and the same time at the divide. It takes two to three days for flood waters from the upper reaches of the river to reach Summit, so we had good notice of what was coming. I had sent a large boat with four able sailors to handle it to the village of Summit a few days before and went to investigate and see what could be seen. We took on provisions and supplies at Summit, but could get no life preservers. Fortunately we did not require them. We started on our perilous voyage and arrived as near to the divide and dam as we dared to. I need not describe what we saw. The usual description of a flood with the floating and drowned cattle, ruined and floating cottages, beams and other structures, horses and other domestic dead stock and several dead human beings among the wreckage.

We remained sometime to view the turbulent and wild scene and then started on our return voyage on a sea of waters extending further than the eye could see, carrying ruined and floating homes and every kind of floating wreckage,—and arrived tired, weary, exhausted and hungry on dry land at Ashland Avenue and Twelfth Street. All south and west and as far east as the river was under

water. From the readings of the water gauges and in and from other sources, Mr. Cooley and the commission estimated that over 600,000 cubic feet of water per minute went past the divide, the exact amount could not be determined. How much of this water came through the Chicago River and how much went through the Illinois River is simply a matter of conjecture. In addition, the Chicago River had the water from its own drainage area to take care of.

At this time all swing bridges over the river were of wood, Howe trusses with curved top chord, wood turntable, pile center pier and protection, trusses, 21 feet C to C, and sidewalks 6 to 8 feet wide, all operated by one man power. The average cost, if my memory serves me right, was about $12,000 for bridge, foundation and protection complete. Talk about high cost of living. What about the high cost of swing bridges which now cost six or seven or eight hundred thousand dollars! The first change was made by the building of Rush Street Bridge, which was completed in 1884. The structure was built wholly of iron (structural steel was not manufactured) on a concrete foundation. At this time portland cement was not made in this country but was imported from England and Germany. Although a small work was being built by the Standard Oil Company at Werners, N. Y., this radical change in type and increased accommodation led to its adoption at all important streets, such as Clark, Wells, Lake, Jackson, Twelfth, and others. Some still remain while others have been removed and replaced by modern structures.

In these early days all railroad tracks and street crossings were on the same grade, and fatalities and accidents were of daily occurrence, so that t some of the principal crossings viaducts were erected over the tracks, the railroad paying the cost of the part over their tracks, the city for the approaches and damage to private property. The city, to save expense and shorten the length of the approaches, required the floor system be reduced in depth as much as possible and indicated the thickness of the floor frame. The city called for a bid for a viaduct at a certain crossing, the length of spans, width of roadway and sidewalk and such general requirements, the bidders to furnish their own designs for the structure and the price. As the contract was always awarded to the lowest bidder, it was simply a competition to see who could design the cheapest structure, using the least material and labor. The floor system to save depth was, except in one case, of six-inch I beams, hanging from bottom chord of trusses, which were 21 feet C to C, with overhanging sidewalks. These I beams of iron were spaced 3 to 4 feet C to C. On these were laid stringers 6 inches by 4 inches deep about 12 inches C to C; on top of these, 3 inch oak flooring spiked to the stringers. On the viaduct at North Halsted and Kinzie over the tracks of the

NOTE: The drainage canal has a capacity through the rock cut of 600,000 cubic feet per minute; earth of 300,000 cubic feet. This to be dredged and enlarged as occasion requires. The Desplaines River is in the Mississippi Valley, the Chicago River in the St. Lawrence Valley.

C. M. & St. P. and the C. & N. W. railroads, this floor system was still further reduced in depth by dispensing with the 6x4 stringers and using 6-inch I bars with a 2x6 bolted to the side. I ask the bridge engineers present if they can design a thinner floor system. They served their purpose at that time and carried the street cars and traffic over safely.

The requirements called for a fiber strain of not exceeding 10,000 pounds per square inch for the iron I beams. Was it complied with? The next change were bids asked on designs furnished by the city, first, for the crossing at South Halsted, Blue Island Avenue over the track of the C. B. & Q. Railroad, where two 12-inch I beams were used with 3x12 joists resting on the lower flange, covered with two thicknesses of 3-inch, forming the floor. Improvement was made in every succeeding design but there are still many viaducts over the railroad tracks adjacent to the river which were built over twenty-five years ago or soon after.

I now close these disconnected and scattering remarks, and at the one hundredth anniversary meeting someone of you may give some reminiscence of to-day. You may smile but there are now present more members younger than I was fifty years ago.

Greetings and Congratulations

THE following letters and telegrams were received by the Society from members who were unable to attend the Fiftieth anniversary celebration:

"I was surprised on perusing the printed matter, enclosed in your kind letter of 21st instant, to note the program arranged to celebrate, shall I say, the fiftieth anniversary of the Western Society of Engineers. Methinks the spirit of the past, the spirit of the present and the spirit of the future might brigade their forces of reminiscence, work and determination to make the anniversary an event never to be forgotten in the annals of the society; and my sincere regret is that I find it impossible to participate.

"A semi-centenary of an engineering society very naturally, it seems to me, marks an epoch in its career, because our semi-centenaries are limited in number, the profession being only about 150 years old. Yet in our fifty years of existence the society has maintained such a fine spirit that its foundation may be relied on for whatever future work may be undertaken.

"The time seems to be opportune for a well sustained campaign for an enlarged membership list, and also for further development of its allied sections. In view of the conditions which the great war has left men to deal with, it looks as though "urgent progress" must be the watchwords.

"It has long been my opinion that there should be developed a much closer relationship between the members of the municipal engineering sections and the communities themselves—a better mutual understanding and helpfulness. The education of an engineer, his practice and development as a man, so broadens him out both as to his professional work and his human sympathies, that to include in his duties that of community advisor and leader, looks like a very natural possibility, and it might surely be a stepping stone to higher ideals.

"I shall hope to hear that this semi-centenary has been a great success with many assured promises that its good work will be both maintained and enlarged to meet the great work of reconstruction ahead."

JOHN W. WESTON.

"It is with great regret that I find attendance at the annual meeting of the American Society for Testing Materials, in Atlantic City, will make it impossible for me to unite in the celebration of the fiftieth anniversary of our Western Society of Engineers. As I am scheduled to take part in the memorial meeting for Dr. Marburg, as well as to preside at one of the technical sessions, it is imperative that I attend the Atlantic City meeting. I had hoped that in some way I could take care of both the western and eastern engagements, but it cannot be done.

"You will please permit me to extend to the members of the Western Society of Engineers my heartiest congratulations upon their fiftieth anniversary, and earnest wishes for the continued prosperity of the Society. Under your able direction, I am certain that the progressive movement which you have caused to be inaugurated will be successful and that the future of the Western Society of Engineers will be all that its most loyal and devoted friends can wish." ROBERT W. HUNT.

"I greatly regret that I was absent at the fiftieth anniversary meeting. I also greatly regret that, on account of lack of time, on account of preparing to go out of town, I was unable to write such a letter as I would have liked to have written, and such as I am sure you would have preferred if any letter at all were received from me. I am sure, however, that you had a very enjoyable time."

BION J. ARNOLD.

"I regret exceedingly that it will be impossible for me to be present at the fiftieth anniversary meeting of the Western Society of Engineers. But if I am unable to be present in person I shall surely be with you in spirit; and I wish to send a greeting to the Society and to all those whom a kind Providence has permitted to be present to commemorate the close of the first half century of the Society's work.

"I have always felt a deep interest in the Western Society of Engineers and shall look back to the associations formed during my period of active work in the Society with the most pleasant recollections.

"I think the Society may well feel proud of its first fifty years of work; and if I do not mistake the signs of the times, the next fifty years will mark an advance, compared with which the first fifty will seem insignificant. The engineer some day will have come into his own; and when he has, the Western Society of Engineers will have contributed its share to his achievement."

W. C. ARMSTRONG.

"I sincerely regret that I shall be unable to attend the fiftieth anniversary meeting of the Society. I send my heartiest congratulations and best wishes and feel assured that the future of the Society is brighter than it has been at any time in the past and that its sphere of usefulness will be greatly enlarged in the execution of the plans now being worked out by the present able president and board." EDWARD C. CARTER.

"Greatly regretting my inability to attend the anniversary exercises I send my hearty congratulations on the great progress made by the Society and all good wishes for its future advancement in the good work it has in hand for the betterment of the engineering profession and for the public welfare." HIERO B. HORR.

"I keenly regret my inability to attend the fiftieth anniversary of the society. The place it has held amongst the engineering societies of the country is little short of marvelous and we can feel assured it will take no backward step during the second half century of its life. I wish to congratulate you, the Society and the secretary upon its splendid work during your administration."

William B. Jackson.

"I heartily regret that a business engagement requires me to leave the city for Washington today and that I will be unable to return in sufficient time to be present at the meeting of the Society.

"Great changes have occurred in the Society during the thirty years covered by my membership. These changes are no greater than like changes in general conditions. In the old days the Society was one of the chief means by which engineers could acquaint themselves with the work being done by brother engineers, thus keeping themselves abreast of the times.

"The reading of papers and the publication of the Journal was therefore of the first importance. While these activities are still valuable, they are hardly of such primary importance as formerly, because of the growth and activity of the technical press. To my mind this has made desirable some change in the objective of our Society. I feel that we as members of the Society are to be congratulated upon the ability and vision of the present officers of the Society who realize the changes in conditions and are taking steps to meet these changes.

"With kind regards and best wishes for a successful reunion meeting."

E. H. Lee.

Résumé of the Activities of the 108th Engineers at Home and Abroad

History of the Regiment Teaches the Importance of Preparedness, and Discloses the Strength of American Character in Overcoming Difficulties, Even When Handicapped

By Col. Henry A. Allen

IT certainly is a great honor, as well as a very great pleasure, to have had my regiment presented with colors by the Western Society of Engineers. You can appreciate the significance of it. In fact, I know we can say we had a real engineer regiment; and it certainly was right, was appropriate, that the colors should be presented by this well-known and able body of engineers.

The presentation of the colors, as you will remember, was on August 27, 1917. This was at one of our first formations, we at that time not being under arms. But most of our men had uniforms and the ceremony was strictly military, and I believe a most impressive ceremony conducted with attention to all the fine points. I can tell you we felt proud of those colors, then, and we certainly feel proud of them now. It was a big task to recruit and form a regiment of engineers. We were not authorized until May 17, 1917, and all the other regiments, the United States Army and all, had been organizing and recruiting. We came, as it were, very late in the game. But with the assistance of the Citizens' Unit and of the engineers of Chicago, we were enabled on July 25, on the call for mobilization, to go in at the then maximum strength. Our organization was a voluntary organization, as you know. Shortly after arriving at Camp Logan, on September 11, we received orders to increase the regiment by practically six hundred additional men. I sent Lieutenant Hudson back to Chicago and by his association with and the assitance of the Citizens' Unit and the United States Recruiting Service, we soon had in our regiment the additional maximum number allowed. Camp Logan, as a rule, did not have such a very good climate. Previous to the time of our arrival there it had been raining very hard, but the morning of our arrival the weather broke and we had practically pleasant weather all the rest of the time, barring a few cold days in winter. But one must expect some rough weather if one is going to be a real soldier.

The selection of officers was a very difficult proposition, as was also the selection of non-coms. We had but two or three officers that were at all equipped to drill the men. One of them had at one time been with Company A, which had been authorized four years previously, and two or three others had had a certain amount of training, but it was not engineering training of the continuous, and you might say intensive, kind. I might mention that this idea that you can train officers in a three months' training period,—officers that really know how to be officers and how to

take care of the men,—is simply pure bunk. It takes two years to train a soldier and six years to train an officer. Of course, we got away with it, at the expense of a lot of poor fellows buried beneath the sod in France, and they wouldn't have been buried had we been better prepared with equipment and better officers. It isn't the fault of the officers or of the regular army, but the fault of all of us. You can't learn these things entirely in the abstract. You have to have your hand on the throttle. When you are commanding men you must know what it means to handle them. You can't go to work and take out your book and turn over to page so and so and see what is to be done. You must know automatically, and on the second. You have to know how to take care of the men, know their wants and needs, how much they can stand. You have to keep them from getting chafed. You have to keep their spirits up. There are hundreds of things an officer learns, and it takes a long time to learn them. It takes at least two years to give the man a habit of becoming a soldier. You must remember that a piano player does not know how to play or become a player until he forgets about counting one, two, three, and his fingers automatically hit the keys. It is the same with the soldier. He must go through his motions automatically, and keep his mind on what he has to accomplish, on the movements of the enemy, and what is in front of him. If he has been properly trained, his muscles involuntarily do that which is best for him to do at the time it is best for him to do it. The American soldier makes one of the best, if not the best, soldier in the world.

The question has been asked, "Can you properly discipline, or rather, can you bring under proper discipline, the American youth?" That issue should not be raised, because bringing it up is simply to attack the stability of our government. The rules and regulations governing the United States Army are part of our laws and if the citizens do not obey them we are sure in a bad way. As a matter of fact, the men are very quick to grasp the necessity for discipline. No man is properly trained unless he obeys, not because he is afraid of punishment if he does not obey, but when he knows why he should obey. An officer must have more training than his men. That stands to reason. In other words, if he hasn't, how can he instruct his men? The men are very slow to give confidence to an officer. He has to prove himself to be an officer before he gets their full confidence. In a regiment there are 1800 pairs of eyes, 1800 brains, 1800 viewpoints that are going to criticize the colonel. There are 250 men in each company that are going to criticize the captain of that company. There are 750 men in each battalion that are going to criticize the battalion commander, and each one of them from a different viewpoint, and believe me, you are running a real gauntlet.

Our officers did the best they could. Some of them were particularly skillful; others again fell by the wayside. They did the best they could, most of them, but, as I said, we did not give them

an opportunity to learn. If you want to handle a supply division you may be able to figure out just how many thousand pounds of rations, how much forage, how much of this and that, but it is one thing to be able to figure and pass the examination and it is another thing to know how it sizes up and how you are going to handle it and get it forward. You have to know what the difficulties are, you have got to be in the game. You must have practice. You know yourself you cannot train an ordinary clerk to become a good clerk in less than two years, and when it comes to making good salesmen it takes three or four years, and here you expect to train officers to handle the lives of men, to stand by our country and fight its battles—and on their ability to make good the ability of our country rests—and you expect to train them with three months here and four months there. It can't be done. We are engineers and we know we have to build from the ground up. Sky hooks are not very dependable. We have to get right down to the matter, and if we wish to have a country that is prepared and a country that can hold its own in any part of the world, we must prepare for it. Let's go at it like real men. Two years' training for men, a longer time for officers,—go at it right. Let's not camouflage and say it can't be done. It can be done, but the task rests upon us to produce real men to put it through. We had better start right; force it through right.

We must remember that once in a while we have these unaccountable convulsions and we have revolutions in society, and they make great changes sometimes, very radical changes, quickly. But, as a rule, radical changes may be said to work slowly. Through certain well ordained and well recognized immutable laws, that system, of rocks, that fauna or flora, that genera, that becomes passive soon sluffs out. It is only the steadily aggressive in nature that makes landmarks along the line of march of nations to their destinies. We must not forget that. Draper said, "That man is the architect of society." Society is made up of individuals; nations are made up of societies. We have a great many, unfortunately, in our country, who advocate abolishing football and a few other of the college athletic sports, because a few have been hurt. They would stop boxing. They would knock out the army and the navy. If they had their way we would have a set of pink tea, slap you on the wrist bunch of Johnnies, a fine lot of guardians to act in case of trouble. You have to have men with red corpuscles. It's right and left to the jaw all the time. That is what makes soldiers. It makes men. I believe that had Germany taught its soldiers how to box and how to play baseball and to play football she would have won this war long before we came over. Individual training is essential. I believe that if you take the average German soldier and put him alongside an American soldier, both being well trained under their respective conditions, that the American soldier will win every time on even weights, because he is more aggressive.

He learns boxing, games that teach him to be aggressive and alert, giving him nerve. As I said, right and left to the jaw.

We oftentimes have heard the analogy of the melting pot applied to our nationality. In my mind this is a very poor analogy. As you all know, the melting of two or more metals together forms an alloy. We don't want an alloy; we want pure gold, true American citizenship. We certainly cannot get it by race; as we are a mixture of many races. We can get it by a proper universal military service. This should be continuous, of at least two years' duration. Here men of different races and creeds, of different political parties and beliefs, of different physical developments and builds, of different trades and professions, different schools and educations are brought together shoulder to shoulder. They rub up against one another; they naturally interchange ideas. Companionships are formed. They will introduce an esprit de corps among themselves. This companionship tends to mutual respect for one another's opinions. The value of intermingling, getting the respect of one man for another is one of the greatest essentials in a government. But to bring this about you must have trained instructors. Therefore, it seems to me that this universal service would be the greatest college of American citizenship that could be created. It is only through ideas in common that we can get a true nationality, a feeling of fighting but for one flag.

I wish to bring this to your attention in a brief way, because it is all important. Our history shows that after every war the fighting man is first told, "Why, we will see that everything is made good; you didn't have many good things to fight with, but you went in and fought and although you were up against great odds you fought very bravely and you won and brought glory to our nation, and we will see to it that unpreparedness does not happen again." But what happens? After every war the soldiers are soon forgotten. Preparedness is essential. We now have a good many million men who have gotten an idea of the necessity for training. Some of them have been very efficiently trained. But it requires more training. The officers that have commenced their education, many of them, must have the finishing touches. Give them more opportunity to get into the finer points of the game, to be better qualified for the military scope of the game. It is an engineering problem, a vast, big problem, with so many diversified points that it requires constant and continual training. Take for instance "liaison," the keeping in proper communication with the various units of the army, your own units, the divisions on each side of you, and of your artillery and of your air force and with the base of supplies,—it is a very difficult thing to learn. Time and time again the battle has been lost or men sacrificed because of imperfect knowledge of liaison. It takes battle problem after battle problem to become expert in that alone, to say nothing of the thousand and one other points of the game.

The 108th Engineers were trained at Camp Logan. At first

there were a lot of them who thought the colonel was too particular or too strict, but that didn't make any difference to the colonel; he had to keep right at it. It is a difficult task to have to train your officers at the same time you are training the men. It meant taking the officers out to drill and then drilling the non-coms, and then let the officer see how the company should be drilled, and try to keep the officers ahead of the men so the men wouldn't feel they knew as much or more than the officers. While we were down there we got some very fine training. Our engineering work necessitated the making of notes and estimates the same as required in the building of some of the modern structures in cities. It stands to reason that only a few learned the finer points, and the majority got only a smattering. We were a very well drilled regiment when in April we were given our general final inspections as regards our requipment. We were pronounced the best equipped regiment in the entire army of the United States after final inspection was held. We had taken particular pains to have as far as possible all our boxes made of uniform size. For harness, for instance, we adopted a 24 in. width by a 38½ in. length. The depth would vary depending upon the contents. There were a few odds and ends that required larger boxes. The main idea was to have our boxes uniform in size so when we landed in France we would look like a military organization, and not like the old lady with the bird cage and the bundles. Everything was marked properly in accordance with rules and regulations. We arrived at Camp Merritt and had an inspection there at which we were obliged to throw away some of our good uniforms and secured some that were not so good. It kept the captains making out requisitions after requisitions. It was a pretty stiff task. It certainly was a queer kind of an inspection. However, that made the second time we were fully equipped. On May 8 we boarded the George Washington.

In the meantime during our sojourn down in Camp Logan the colonel received, like all other officers, a stack of rules and regulations and matter pertaining to the various battles that had taken place and how to act as the C. E. of a division. In fact, about a cubic meter of literature. When I got on board ship I intended to read this one cubic meter of knowledge and become a real educated colonel. We had been on board ship about three hours when I received notification of being appointed troop commander. There were about 5400 men on board. There were among them 478 officers, advance school details, and 2300 men of a labor battalion, mostly from South and North Carolina. They had never been in companies before and their officers had just been assigned the day before embarkation. Our colored friends had an idea that they could go to that company which had the best looking captain or something like that, and they milled around so that it took us practically five days to stop the milling and get them straightened out, and practically ten days before we got them set.

Many rather amusing instances occurred on the journey over. Always, in time of war, we have abandon ship drill every day. Sometimes we would be informed when it was coming and at other times it would be sprung on us at any old hour. Each man aboard, completely equipped with life preserver had to go to his part of the ship in the neighborhood of the boat or raft assigned to him. One day I was in the passage down below watching them pass by, two laborers came along and ran into one another. One said, "Whar is youah goin'?" "Why I'se goin' up to drownin' drill." Another during rough weather was heard to remark, "Dis here nigger is sure goin' to be a European nigger, unless they builds a bridge back to the United States."

We had a very delightful cruise indeed and arrived in Brest on May 18 after ten days out. We marched to the famous old Pontanezan Barracks. I believe we were the first divisional engineers to go through this particular camp. No one had done much work there before we came.

We built the Y. M. C. A. building, put up a lot of barracks, started the water works and ran a main electric pole line. We were highly complimented for the efficiency shown in getting out work rapidly and in first class manner.

We then entrained on the "8 Chevaux and 40 Hommes," as they call them. We apparently traveled all over France, but in due time arrived at what is called a staging camp. Company A was left at this particular place to bore a well and fix up the water works and take care of the staging of following troops. The remainder of the regiment went on to Avesnes, Tailly and Etrejust. Here we were supposed to be in our first training camp. I might mention that it was a rather hard march of 17 miles over pretty rough roads, but the men stood it finely, carried 55 pound packs, and I don't believe any of them fell by the way side. It was really the first long march, and very tiresome. After we had reached Tailly and just gotten alongside a big stone wall of the place we were going to stop, bing! bing! bing! three air bombs went off. They weren't very close to us, but we thought they were right on top of us. The anti-aircraft guns began to bark, and I was just trying to figure out how many guns an American colonel was entitled to when we went into a new billet. Our rifles were changed from Springfields to Enfields. Believe me, it broke our hearts to have to put our beautiful Springfields on the trucks and see sights busted off, and otherwise roughly handled. The men were all a little skeptical about whether the Enfields would shoot straight or not, but they proved to be pretty accurate rifles.

Shortly after we were issued the Enfields we were asked if we were ready to move. I told them we would not go forward until they gave us properly fitted gas masks. Gas chambers were fixed up and then every man present in the regiment was properly fitted out. We then marched to Airaines and from there were taken by train to Poulainville. From here companies marched to

the various stations assigned to us at the front. Some of our English guides lost their way, and some of our men had a very hard march of 35 kilometers. This was pretty tough to march this long distance after the hard hot ride on the trains. Here three companies were attached to the Third British Corps and three with headquarters and engineer train with the Australian Corps.

I will not go into details, but I am very glad indeed that we had this experience under the British. They have many things that are well worth knowing and copying. We learned a great deal from them, especially practical work. The C. E. of the Fourth Army said that the R. E.'s were badly shot up and the general of the Fourth Army asked me to allow the regiment to take its place with the R. E.'s. That was on June 13, and from that time on the regiment was in the zones of operations during the balance of the war. They built every night at about nine P. M., and took down at four o'clock the next morning pontoon bridges across the Somme at Carbie. That was the first experience under shell fire and gas. Then the regiment was at times out on patrols, at observation posts and took an active part in the light railway operations. We had an opportunity of sending the topographic squad down to the Fifth Survey Battalion to study English battery fixation, flash spotting, sound ranging, interpretation of aerial photographs and map reproduction. Then I sent a detail over to the searchlight division. Advantage was taken of every opportunity to learn in actual service what might be required or what an engineering regiment might be called upon to do. We left no stone unturned to become as skilled as we possibly could. The companies became very expert in removing the booby traps and demolitions, and both the removing of bridges and the placing of bridges. Here we got some equipment.

I might mention that after we arrived at Brest we couldn't get any of our equipment. We, however, had certain of our regimental equipment and the company boxes, etc., and they were loaded on the train. Two cars were put off in which we had our ammunition and the bags of the men and very important regimental boxes containing company records, etc. These cars were put off on account of hot bearings, they said. Although I did not consider them hot they would not take them any farther. This fact we reported, according to the rules and regulations, but we saw very little of it afterwards. When we did finally get some of it the men found all their barrack bags ripped open and gutted. I might mention that the colors given us by the Government were in one of the boxes and we have never received that color. Many of our important records were lost, besides tools, etc. When we arrived at our training area we had none of our equipment, except the personnel equipment. On Thanksgiving Day of last year the regiment was at Saint Remy. The companies there built a fine grand stand for the speakers and band. The regiment was assembled around in groups and I said our condition reminded me, starting as

we did, with a complete equipment and landing, as we did, at our training sector, of "Mary had a little lamb; its fleece was white as snow. She took it down to Pittsburgh. Now look at the damn thing!"

We got some equipment from the British, but their formation was different from ours. They had three companies or one battalion, as they call it, commanded by a lieutenant-colonel. We did get quite a number of good horses and British wagons and equipment which really had many good points and were very fine. We used them all through the war and had most of that equipment with us when we turned it in two or three months ago.

We were in all those battles on the Somme front, the Somme defensive and the Somme offensive, the July fourth operation, and that of Chippeli Ridge on August 8, where the two companies, D and F, built the road, twenty meters wide and four thousand meters long, for the advance of the British cavalry, for which they were cited. Company E at Villers-Bretonneaux did some fine work on the railroad. Other companies, B and C up at Lavierville and other places were doing their part, not only to protect the lines but to advance them.

I was very much worried because the discipline of the Australians behind the lines was not very good and it is difficult to keep a regiment up to discipline when your neighbors are inclined to be lax. The Canadians at first were much like the Australians, but later greatly improved their discipline. They were all good fighters. I want to say that discipline is one of the essentials to save the lives of your men, and also to win battles. You will find that our men have all the grit and spirit and punch that any other soldiers have and they go at it like true sports. They are there all the time. They don't have to be a bunch of rough necks to do it either. This hard boiled stuff talk is detrimental to service.

From here we went to the Verdun Sector. You already have heard of the crossing of Forge Creek, the building of the eight passerelles under machine gun and shell fire, out there in the morning, removing mines from the passerelles that the Germans had planted, building eleven bridges and putting the troops over. Each non-com was assigned by his captain to do certain work, and they worked out there under machine gun, rifle and artillery fire as if they were working out here in Grant Park. When that work was done they connected our tape with the infantry tape in front of the "jump-off" trench and carried it forward up to the enemy machine guns.

Our engineers had crossed Forge Creek twelve times before the jump off, and in that way obtained very valuable information for the infantry. The year previous the French had lost about five thousand men trying to get across Forge, but by putting the roads across where they didn't expect us to put them, we got across with very little loss.

I might mention that the engineers were able to keep the direc-

tion very nicely for the infantry, on account of knowing the terrain well, and also on account of being familiar with the use of the compass.

This story is told by Colonel Bullington of the 132nd. He said, "Colonel, I was leading my battalion over one of the passerelles, and had just gotten over one of the bridges when I heard somebody yell, 'Give 'em Hell, boys, give 'em Hell.' 'Who's that?' I asked. 'Sergeant of the 108th Engineers,' was the reply."

After companies D and E had finished this work they were to stay and put the bridges in good repair, and when that was done go back to their billets and await further orders. Companies C and F were to follow immediately after the assault eschelon and put up strong points and organize the captured terrain agaist counter attacks. During the advance the engineers found themselves in the front holding a portion of the front line. The next day all were early at work on the roads, so the following morning the horse transport was able to take rations and supplies up to the infantry.

I recommend that in the re-organization of sapper engineer regiments more equipment be provided. A great many figure that mobility is a question of road space. That is not so. It is a question of how quickly you can get a required number of men or quantity of material or supplies to a certain point. We did not have the equipment and the men had to carry material, piece by piece, which consumed time. They worked for long periods without rest, sixteen hours a day very often, but, with all the hardships they had to endure, each day saw them smile.

Then we built the bridges across the Meuse. At the Meuse it was necessary to bridge the river. One bridge was 120 feet long, in 12 feet of water, and the other 156 feet long, in sixteen feet of water. That was a very difficult bridge to build. The first bridge was started about 5 A. M., and soon after I received word that they were shelling it hard and that it could not be built. I said, "That bridge has got to be built." I went forward to observe operations. They had to carry the material about two kilometers in direct enemy observation. Just as I reached the bridge Captain Bready came to me and said, "Colonel, the bridge is finished." As I went across the open ground I was thinking mighty hard of what could be done in case we had been shot up and could not build the bridge. But the boys had built it, although they were shelled incessantly. One shell killed two and wounded seven. One of them was killed outright and the other one died afterwards.

The second bridge was started at 11:30 and was built under direct enemy observation, under shell fire for five and a half hours, and also machine gun fire, for two hours. I want to tell you the shells were falling all around them at the rate of about ninety-five an hour. However, only three slight casualties occurred. They put that bridge across and never turned a hair. It was a very fine piece of work, and a long bridge. Some of the material we were able to bring from our engineer dump, but most of it we got from

the German passerelles, which were carried over by hand. We then put in a section of light railway which we got from the Germans. After that we fixed the main bridge at Consenvoye and started another. We were in charge of all engineering work in this sector until on October 18 we were ordered away. Shelling had been intermittent, but continual, and on the forward roads there fell from two to three hundred shells a day. This was a very live sector on the ground and also in the air, and we saw some wonderful feats performed by both sides. One in particular was when a German aviator came from somewhere in the air and got four of our observation balloons, one right after the other. It was a very clever piece of work, and although we did not like to see our observation balloons going that way, we could not help giving him a little cheer, showing what real sports the Americans are. It was a wonderful piece of work. Of course, we couldn't see what our aviators were doing on the other side.

After October 18 we marched to the Troyon-Chaillon sectors. Here we went on the roads again, and we now had three hundred kilometers of road to handle. And I might mention that all during this time our motor transportation was bad. Every engineer regiment is supposed to have one large car in the train and three in the regiment. We were given one, a second hand car. That is all we had, and we did not have that until pretty late in the game. We had eleven side cars out of eighteen, and you can appreciate that when you have to run without lights and at night time, sometimes very dark, that such machines naturally get bumped up. It was also very difficult to get repairs for them. If anything could make a commanding officer crazy it was in not being able to get where he ought to be at the right time. The result was we had to function the best we could. We kicked, but we went to it just the same. We did not stop and sit down to worry about it. They had a lot of stuff back there in S. O. S., but we couldn't get it. Why I don't know, but we couldn't and had we been going against an enemy that was not retreating it might have lost the battles for us. I have heard the C. E.'s of other divisions make similar complaints.

The engineers worked hard, of course, they had to. They had to build delousers, latrines, fix billets, build bridges and roads, extend the light railroads, and build water works. They had water work engineer battalions but they were not always up there, so we had to do a lot of such work ourselves. There was no end of detail work to be done. At last, on November 11, the Armistice was declared and we started to clean up. The engineers, of course, have a lot of work to do to help the division out, so you are busy all the time; you don't get much rest, and of course your shoes wear out more rapidly than they otherwise would. But the spirit of the men was good all the time. We were ordered to march forward about 180 kilometers. This was just at the time the rainy season commenced, and it was tough going, soaked day after day. We

used the trucks to take the blankets of each company forward, and in that way when the men arrived they always had dry blankets. Also, when possible, they had hot coffee on arriving at destination. We reached a point where three companies were ordered to go to one billetting area and three to another, and headquarters and train to another. On this last day it was cold, chilly and sleety. I felt most uncomfortable, so you know how the men must have been. About forty per company were walking practically on their bare feet. I had to leave thirty men back at the dumps because they had no shoes to march in. Happening to come up over a little hill a couple hundred yards away, they saw the colonel and broke into the swinging cadence. They were singing lustily as they passed. This was a thirty kilometer wet and rough march. There were but two chafes on the horses during all the march, showing good care and condition.

Shortly after this the regiment was ordered to Echternach and Berdorf. It is not far from Beford, where are the wonderful old ruins of an old castle around which is based the story of "The Prisoner of Zenda." Here we went into training and tried to get our equipment, uniforms and shoes. This remained our winter barracks. When we first arrived they would not give us any billets, but finally when they found how the men behaved we were all given billets. In fact in less than five days the men were sleeping on big feather beds and given cakes and milk. The men were really treated fine here. They were allowed to have their dances, and I will say they conducted their dances in a high grade manner. It was a pleasure to note the enjoyment gotten out of these dances by both the men and the citizens. From here we were ordered down to Remich, about forty kilometers. After we had been down there about five days we were ordered back again. The corps could not get more than eighteen billets. When the advance detail was sent on two trucks into Echternach, before the return of the regiment. On arriving in the middle of the square the little boys and little girls rushed out and grabbed packs and rifles and escorted the men back to their old billets. This showed very well the good feeling they had for the men.

Two days before we entrained I was asked to be in my billet at eight o'clock. Major Guilfoil also came around. We heard a commotion and looked down the street and found it filled with men and women. We went down and stood on the steps. The Echternach band played the Luxemburg national air and ours. One of the very charming ladies, said in English she wanted to have the Colonel tell his men how much the citizens of the city appreciated the good conduct of the men, and also to tell the commanding general that they thought the 108th Engineers was one of the smartest regiments in the United States Army. She ended by saying, "In token of our sentiments and best wishes we ask you to accept this bouquet of flowers." I then endeavored to answer back in a compound speech of French and German.

Major Guilfoil started on French but shifted quickly to English. One lady said, "We wish to notify the major of the first battalion of our appreciation of the the fact that the men and officers were gentlemen and we were glad to have them with us." He also accepted a bouquet of flowers. Then the town major was presented a bouquet of flowers. After this we marched around the town. It was really a pretty sight and showed that they were really fond of us. The fact that discipline was maintained at all times, that the men acted as American soldiers should act all the way through, resulted in appreciation by the citizens. My idea was that Luxemburg being independent, it was our duty to help along diplomacy and leave a good impression of what Americans and American soldiers are.

After many meanderings through France, we arrived at Brest. Eight days later, we embarked on the U. S. S. Harrisburg. One instance occurred which was very bad, and of which I made a complaint. At 3:15 we were given orders to retain three officers of the train and sixteen of the remainder of the regiment at Brest because the space on board ship had been given to some English war brides going to the United States. I made a protest that it was absolutely unmilitary and unjust to separate officers who had gone all the way through with the regiment, and stated that nothing more greatly interfered with military discipline than acts of this kind. Of course it didn't do any good and we had to leave them behind. These officers and men arrived in time to join the regiment at Camp Mills. And then, on June 4, we had our wonderful reception, in which the Western Society of Engineers and other friends of ours from Chicago greeted the troops as we came home. I want to say that was far beyond the expectation of the officers and men, and they are talking about it yet.

Through all the four and a half months, outside of about eighteen days of changing sectors, we were in the front zone of operations continuously. The casualties were less than 110, of which the actual deaths in battle amounted to about 20 or 22. This low loss is due to a high morale, always working to a plan, good discipline and training, and, of course, luck, which always enters into the military game, as it does into many other games with which we are familiar. Before leaving Camp Mills in one of my last speeches to the men I said, "Now remember that you are going back to Chicago and home, and, that, that bing! bing! stuff is what pulls you through. Be snappy! March up there with a swing; show them you are real soldiers and why you won; that will make them all smile."

I wish to say one more thing about the colors that were presented by this Society. The standard, the regimental colors, was marked "First Regiment, Illinois Engineers." We also received a set of colors from the Chicago *Daily News* in which the regimental colors were marked "108th Engineers." I sent the "Red, White and Blue" of those colors and the flag we saw here tonight to Spring-

field, Ill., where it remained during the war, but the "Red, White and Blue" presented by you went all the way through and is now at Springfield, turned in by the regiment; also the ribbons that we received of the different major engagements that we were in. When the time comes those colors can be brought back to Chicago, if it is so determined and desired, after the formation of a new regiment. Some of the men and officers accosted me today and wanted to know when we were going to start the new regiment, to be called the 108th Engineers.

We did not use our flags. As a matter of fact, the last time I had these flags out was in Tailly on Decoration Day a year ago, when I was informed by the commanding general I was not to display them again because the French might take offense at the display of our flags in that part of the country. I unbent them from the pikes. Our pikes, some of them, were in those boxes we didn't get, but the colors were always kept either in my trunk or in my safe, so they were always with us. They were with us throughout the campaign and with us until we were mustered out, when they were taken by the government orders to Springfield, where they now are.

As engineers, we are used to analyzing problems, and we should use our efforts to see that the lessons learned from this war are made use of and that laws are enacted, so that never again will our soldiers be put up against difficulties they should not be up against. In other words, do not allow murder of your American soldiers, because of unpreparedness. They get killed and hurt fast enough in battle without having to be murdered by their own citizens. That is what it means when you send men that are not trained forward, or send them into battle under the command of officers who are not trained. There is no excuse for it.

I want to thank you one and all and tell you how proud we are, and were, to receive the colors; how proud we are to come back and meet you all, for the good will you have shown us, for the courage you lent us when we were away. We knew you were all back of us and we feel that we did our best to do our duty in the fields of action, so that none of you will have any other feeling than of honor to perpetuate that regiment. It has traditions now, traditions of which we may all be proud and of which we can boast. I know you will all be with us in the future, as you were in the past, through the campaign of which victory at last crowned the efforts of the United States Army.

Obituary

Lewis A. Nichols, who died in his home in Chicago, Ill., on March 5, 1919, was born in Florence, Italy, on August 26, 1851, of American parents. His mother died in Rome, Italy, in 1856. His father returned to America with the remainder of his family in July, 1857.

The family settled in Danvers, Mass., where his father died in 1858, leaving him an orphan at the age of seven. He attended the common schools and the high school of Danvers, and entered the Massachusetts Agricultural College at Amherst in its pioneer class in 1867, graduating from that institution in 1871, and choosing as a profession that of civil engineer.

During the fall of 1871, he was engaged in laying out an addition to the city of Fall River, Mass. Near the latter part of 1871 he was employed as leveler in a locating party on the Massachusetts Central Railroad, and in the spring of 1872 he was given charge of that party, finishing the location and construction of a division of that railroad in the fall of 1873.

He was elected city engineer of Chelsea in 1875, a position which he resigned in 1877. From that date until 1908, he was actively engaged in surveys or construction of railroads in almost every part of this country and parts of Mexico.

He married Carrie W. Putnam in Danvers in 1879. In 1908 he gave up the active practice of his profession except as a consulting engineer, and since then devoted most of his time to the interests of the Chicago Steel Tape Co., a corporation which he organized in 1903.

He was a member of the American Society of Civil Engineers, a member of the Western Society of Engineers and several other engineering societies. He was also a member of the Woodlawn Park Lodge A. F. & A. M. of Chicago.

Proceedings of the Society

Meeting No. 1048, September 15, 1919.

This was the first general meeting of the Society for the 1919-1920 season. There were 110 present. The subject under discussion for the evening was the "Economic Future of Transportation Utilities." J. R. Bibbins, M. W. S. E., presented the first paper giving the history of transportation difficulties. The electric railway was used as a typical example of a transportation utility. P. J. Kealey, president, Kansas City Railways Co., was unable to be present but sent a paper on "Valuation—and Accruing Depreciation," which was read by the secretary. "The Actuarial Problem" was discussed by John Jirgal of Hagenah and Ericson. George Weston, M. W. S. E., of Philadelphia, presented a paper on "Electric Railway Policy." Much interesting discussion was brought out at this meeting inasmuch as the subject in hand was one of intense interest to the country at the time.

Meeting No. 1049, September 15, 1919.

This was a meeting of the Bridge and Structural Section of the Society, at which 125 members and guests were present. Dr. J. A. L. Waddell, M. W. S. E., consulting engineer of Kansas City, presented two papers on "Comparative Economics of Cantilever and Suspension Bridges," and "Economic Span Lengths for Simple Truss Bridges of Various Types of Foundation." These papers, which gave the results of Dr. Waddell's tests and calculations were printed in a previous issue of the Journal and the speaker presented them in abstract form, illustrating his subjects with slides. G. A. Haggander, chairman of the section, presided.

Meeting No. 1050, September 22, 1919.

This was a meeting of the Hydraulic, Sanitary and Municipal Section of the Society. There were 95 present. Langdon Pearse, M. W. S. E., of the Sanitary District of Chicago, presented a paper on the "Packingtown Waste Problem." Chicago's problem of disposing of sewage from Packingtown is one of the greatest questions which comes before the authorities. But after several years of tests, Mr. Pearse pointed out, a plan had been so worked out and tested that it was now possible to embark on a comprehensive plan for the disposal of this waste. The proposal, he said, required that the packers and the sanitary district should work together to put an end to this nuisance. Many engineering, as well as economic features, were brought out by the paper and the discussion following. Mr. Pearse's paper was illustrated with slides.

Meeting No. 1051, September 30, 1919.

This was a meeting at Fullerton Hall, Art Institute, sponsored by the general committee of technical societies of Chicago of which the Western Society is a member. The subject under discussion was "City Zoning." Redistricting of Chicago and the establishment of a zone system has been authorized by the Illinois Legislature. Engineers will have a great part to play in this work and the general committee arranged for this meeting so that local technical men might have the opinions and impressions of an expert on this subject. Dr. Robert H. Whitten, engineer of the City Plan Commission, Cleveland, was the speaker of the evening. Before being engaged by the City of Cleveland, Dr. Whitten served as a member of the New York City Zoning Commission. Dr. Whitten's lecture was illustrated with photographs and diagrams of the zoning systems in New York, Cleveland and St. Louis. He brought out the point that zoning must be undertaken on a comprehensive scale in order to secure the greatest benefits for a city. This meeting was regarded as one of the most successful ever held under the direction of the general committee. There were approximately 200 present.

EDGAR S. NETHERCUT, *Secretary.*

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Purchase of Coal on Specifications

By JOHN HOWATT,
Chief Engineer, Chicago Board of Education.

Presented November 17, 1919

IT may be said that practically all coal is now purchased under a specification of some sort, and consideration should be given to the sort of specification that should be adopted by the different classes of purchasers. The ordinary purchaser of coal in small quantities obtains a price quotation on a specification that calls, for example, for Pocahontas mine run, Franklin County 1¼-inch lump, or Pike County No. 3 nut. Such a specification is very loose and no provision is made in it to see that the coal which the purchaser thinks he is to get is the coal actually delivered. Whoever heard of there being any standard district coal offered for sale on such a specification; yet we know quantities of such coal is delivered to the market. The purchaser thinks he knows what he wants between very wide limits and when he orders it he *may* get it. He will pay the full price and may or may not obtain the full value, depending upon the honesty of the coal dealer.

Such a specification and method of purchase is all in favor of the coal dealer, yet is the form on which the larger portion of the coal is sold and purchased; this is on account of the trouble and expense involved in the purchase of such coal on more exact specifications and the cost and expense of following up the purchase to see that quality specified is delivered. The user of small quantities of coal is thus forced to buy his coal on a general specification as to size and grade only.

This is the field in which the coal salesmen find they can best use their talents and their enthusiasm in the coal they handle is unbounded. In fact the purchase of coal on this basis is largely a matter of personal acquaintance and salesmanship; not a question of the coal that will give the greatest value for the money expended. It is because operators and dealers are so accustomed to selling coal on this method they become over enthusiastic about the quality of the coal from the mine they represent, and are led into exaggerating quality when bidding on more exact specifications; crediting their coal with a higher value than it actually has, and may be forced to suffer a penalty thereby.

This method of purchasing coal is all in favor of the coal dealer and under *normal* conditions should never be resorted to by

corporations or institutions that purchase in large enough quantities to warrant the expense of checking and testing deliveries. Years ago many of the larger users decided coal was too large an item in the cost of their operation to be purchased in a loose, haphazard way that took account of quantity without also taking into account quality; that provided no *measure* of value received for money invested. Specifications of different forms were prepared and put in use, the more common being the specification and award of contracts for coal on a guarantee of coal of a definite size from a definite specified mine, the quality of the coal from which was known to the purchaser. This is a form of purchase used quite extensively today. It is open to the objection that in case of accident or shut down of the particular mine the purchaser is forced on the open market without protection.

For several years this has been a very serious consideration; furthermore it is almost impossible to check the origin of all deliveries, especially if the deliveries are made by wagon to many points, thus making it possible for the contractor to substitute a poorer grade of coal in some of his deliveries; this is especially true if the contract is with a dealer who has a large diversified business handled from the same team tracks or yards; limitation of competition in bidding for the business and difficulty in making an award without charge of favoritism; difficulty in making adjustment on contracts for coal of an inferior quality if found when delivered; difficulty in proving coal is inferior to that named in the contract when origin cannot be proven.

Formerly attempts were made to purchase and pay for coal on evaporative tests, the bidder that agreed to evaporate the greatest number of pounds of water per pound of coal as received being awarded the contract; it was *presumed* the contractor would deliver coal of the same quality as the sample furnished for test throughout the life of the contract. Attempts were made to provide price adjustments on monthly deliveries based upon the result of monthly evaporative tests of the coal delivered. While, of course, the value of a coal could be measured properly by careful evaporative tests, the method proved very cumbersome, loose and possible of uncertain results, and it was actually found in practice to be difficult to prove the quality of the coal based upon such tests when controversy arose. This type of specification has been largely superseded among the purchasers of large quantities of coal, public institutions, etc., by a specification in which the purchase is based upon the chemical analysis and heat value of the coal itself. While the chemical analysis method and the evaporative test method both provide for paying for the coal according to its worth and provide a means of a sort of measuring quality, the analysis method is much less cumbersome; is more scientific and exact, and enables a check of results, a point that should always be considered as protection in the event of controversy between the contractor and the purchaser. It is moreover the one method that can be used to compare results of coal of all kinds under boilers in any location and makes

possible a standard specification especially suitable for the purchase of coal from public funds, as it bases awards of contracts entirely upon the greatest value for the money. However, the mine operators in general are not in favor of selling on this basis, their argument being that they have to pay miners on a per ton basis; that all their costs are on a per ton basis, and, therefore, they should sell on the same basis.

The United States Government was among the first to give thought and action looking toward a standardization of the method of purchasing coal for its different departments. It must be admitted that the ultimate consumer buys coal not for ballast or so that the transporting companies will have more freight to haul, but for its heating qualities. Coal is bought to make steam, and its value as a steam maker depends upon the heat units in it. The United States Government took cognizance of this fact and some sixteen years ago started out to obtain the information about the different coals in the country that it was necessary to obtain in order to intelligently prepare specifications covering the purchase on a heat value basis. Sufficient data had been collected so that in 1907 the Government started to purchase its coal on a scientific basis and this was continued until the extraordinary conditions brought about by the war in 1917, when the heat value method of purchasing coal was abandoned. It was put in effect again by the Government last July, however, and purchases are again made on the B. T. U. basis. Many states, cities and public institutions followed the United States Government in adopting the B. T. U. method of purchasing their coal supply, varying somewhat in the details of specifications and methods, but all attempting more exact specifications that took quality into consideration as well as quantity.

The cost of coal has risen so much that it is more essential than ever that the coal purchaser buys it and pays for it in accordance with its value to him. Many materials are bought in large quantities according to their assayor on a scientific basis, and coal is one material that renders itself readily to analysis that will determine its value. It is true that it cannot be considered a manufactured article, nevertheless the preparation of the coal can be modified to such an extent as to materially effect its value, and the operator that takes the proper precautions and care in the preparation of his output should receive the extra compensation for it that analysis will show it is worth.

Before a consumer should make any attempt to prepare a specification for coal he should try out coals of different sizes and from different coal fields in his boiler plants and obtain information thereby as to what size of coal gives the best results and find out from what fields the coal can be used successfully in his furnaces. Analysis of each coal tried should be obtained. The consumer will then be prepared to specify the size of coal desired and place limits for ash, moisture and heat value, as the basis of a scientific specification for future purchases on the B. T. U. basis; and if the coal is specified further to be free of excessive clinkering and

free burning, the purchaser should be in a position to place contracts for coal not necessarily on the lowest price per ton as bid, but the lowest cost to him for the year's fuel supply, which should in general be the determining factor from the purchaser's standpoint. Of course, it may be advisable on account of weak furnace draft or insufficient boiler capacity to purchase the highest grade coal for some plants regardless of the fact that the price per unit of heat value may be higher; and the selection of coal for stocking or placing in storage must be based on considerations other than costs; but in general the net cost of the fuel per season should be the governing factor for purchasing in quantities under normal conditions. The work done by Prof. Parr of the University of Illinois in his studies and analysis of Illinois coals should be of great assistance in the preparation of specifications for Illinois coals and in the selection of the proper coal to use.

Taking it for granted that all the coals considered in making a selection are free burning and free from excessive clinkering, there are but three things the purchaser of bituminous coal needs to know about it; they are its ash content, its moisture content and its heat value or B. T. U. per pound. All formula used, therefore, in specifications covering the purchase of bituminous coal on the heat value basis should contain the three factors: ash, moisture and B. T. U., the first two being loss factors and the last a credit factor on each pound of coal. This is taking the coal apart as it were and studying what should be charged against each portion of it; a sort of a cost analysis of each pound of coal.

Ash.—All of the non-combustible material left after coal is burned off in the furnace is known as ash. The percentage of ash in coal varies greatly in the different sizes from the same mine, depending upon the part of the vein the coal is taken from and the mine operations. It is greatly increased by the presence of earthly material, slate, stone or shale, and is highest in the fine coal from the bottom of the vein or from the bottom of a shipment. Screened lump and nut coals, therefore, contain the lowest percentage of ash, and fine coal and screenings contain the highest ash content; in fact screenings may and often do contain twice as much ash as nut coal from the same mine. Ash is a factor that may materially reduce the value of a mine output, and as it can be reduced by careful operation and by careful washing, consideration should be given by the mine operator improving or conserving the natural value of his output by keeping the ash content low.

The purchaser must bear in mind that the ash content in coal is very important to him, and if he be wise he will make provision to protect himself against paying for a large tonnage of ash that is a loss to him. For illustration, if the purchaser pays $5 per ton for coal delivered into his bunkers, he is also paying $5 per ton for the ash in the coal. To this must be added the cost of handling and disposing of ashes from the furnaces. This will vary in different plants, depending upon the equipment provided

for ejecting or moving the ashes from the ash pit, and depending upon what must be done with them afterward. Some plants are so located the ashes can be sold or used to advantage for filling; others are located in congested, built-up districts where ashes have to be teamed to dumps several miles. It is costing an average of $1.20 per ton for hauling ashes away from the public schools in Chicago this year. Assuming, therefore, an average cost of 50 cents per ton for ejecting ashes and $1.20 per ton for hauling them, the total cost of the ash to the purchaser of $5 coal would be $6.70 per ton. This is a direct cost and the value received is zero. It is readily seen what a difference there is in the value of a ton of coal of ten per cent ash over a ton of coal of twenty per cent ash; the purchaser will pay 67 cents for the ash in a ton of ten per cent coal and $1.34 for the ash in a ton of twenty per cent coal. If the purchaser is to be protected, therefore, the method of purchase should be one that will make the difference in the cost of a ton of coal to him carry the loss due to the increased ash content.

Besides the loss in theoretical heat value of coal because of its ash content, there is a further actual loss in practice when the ash percentage exceeds a certain limit by reason of the loss in capacity and efficiency of the furnaces on account of clogging of the fires from the ash deposit. In fact coal containing thirty per cent ash cannot be burned at all in many plants and thus has no value. During the coal shortage in the winter of 1917 the writer had experience with screenings that tested thirty-two per cent ash. These screenings would not burn on a chain grate until they had been mixed with a No. 3 nut coal of low ash percentage.

In preparing specifications for coal to be purchased on a test basis, therefore, a maximum limit on the percentage of ash should be named, and a penalty for the ash content in coal over the maximum should be provided, heavy enough so very little such coal would be furnished. The penalty should be on a scale that increases rapidly as the percentage of ash increases. If the ash content is lower than the limit named in the specifications, the contrator should obtain an increased price per ton corresponding to the increased value of the coal.

Were it not for the fact that very frequently coal has to be burned before the result of the test analysis is known, coal exceeding the limits in ash should be rejected, as price adjustment will seldom compensate the purchaser for all of his loss. The rejection of coal purchased on specifications is generally impracticable after delivery has been made, so resort must be had to a heavy penalty for protection.

Two typical specifications making provision for price adjustment to take care of the ash content in coal are noted for illustration, as they represent the latest practice on purchasing coal on a test basis. One is that used by the United States Government and the other is that used by the City of Chicago. In the specifications upon which the government is purchasing its coal this year,

what is termed a standard ash value on a dry basis for the quality of coal it is intended to purchase is established. For any coal received that tests a lower percentage ash than the standard named, the contractor is allowed a bonus of two cents per ton of coal for each per cent the ash is less than the standard. This seems to be based upon a cost of $2 per ton for handling ash. No penalty for ash is deducted unless the ash content is more than two per cent greater than the standard. Where the ash content is more than two per cent in excess of that named as standard, deductions are made from the price to be paid for the coal on a rapidly ascending scale to compensate for the loss in efficiency in the furnaces. In the specification used by the City of Chicago a deduction of one-half cent per ton of coal for each per cent of ash on a dry basis is made on the entire ash content. This is based upon a cost of fifty cents per ton for handling ashes and does not increase the penalty for excessive ash to compensate for the loss in furnace efficiency, and therein does not protect the purchaser against coals being delivered with a high ash content as well as does the specification used by the government. On the other hand, it makes a deduction for all the ash in the coal instead of only that in excess of the limits, and in that regard in more scientific but not as practicable in application at the present time.

Moisture.—Moisture is the other inert content in the coal that the purchaser has to pay for and for which he receives no return. Unlike ash, however, he does not pay to have it removed. There is a question as to whether the moisture is of enough value in the coal to compensate for the loss of heat units in evaporating it in the furnace. Formula used in purchasing coal on a B. T. U. basis as a rule makes no penalty for moisture other than that provided by reducing the coal delivered to a dry basis, by which is meant—from which all moisture is driven out.

Moisture is a factor that changes rapidly. A car of coal may gain or lose a ton of moisture en route from the mine to the consumer, fine coal taking on and giving up moisture most rapidly. It is important, therefore, that for the protection of both the buyer and seller, a coal sample for moisture test should be taken when the coal is weighed at the delivery point. If the coal takes on moisture after being weighed but before being sampled, the contractor will be the loser; but if the coal gives up moisture after being weighed but before being sampled, the purchaser will then be the loser.

The two typical specifications considered before, that used by the government and that used by the City of Chicago, differ in their provision for adjustment of price because of moisture only in their method of application. The government specification provides for a payment based upon the British thermal units in the coal as received, the B. T. U. per pound of coal will thus be automatically reduced in proportion to the amount of moisture in it. The City of Chicago specification provides for payment upon

the British thermal units in the dry coal, but reduces the amount of coal paid for by the amount of moisture in it. The resultant number of heat units in a ton of coal and the price paid the contractor therefor would be identical under either specification.

B. T. U.—Coal is purchased for its heating value, for its ability to convert water into steam, and a measure of this value is a measure of the worth of the coal. The unit of heating is the British Thermal Unit, being the heat required to raise one pound of water one degree Fahrenheit, and the heating possibility of any coal is measured by the number of such heat units in a pound; as the B. T. U. per pound varies as much as 30 per cent between the different commercial Illinois coals, it may be seen that the purchaser can secure what he pays for, heating value, only through a method of purchase that bases payment on the B. T. U. per pound of coal. This is the most important factor in all coal purchases made upon analysis, and in fact such purchases are usually referred to as purchases "on the B. T. U. basis."

In writing proposals for coal to be purchased on a B. T. U. basis, limits for B. T. U. per pound should be named far enough apart so there will be plenty of opportunity for competitive bidding and still limiting the coal to the general quality desired. In comparing bids the lowest bid is determined, as in government specifications, from the cost per million B. T. U. obtained by: multiplying bid price per ton by one million and dividing by 2,000 times value of the B. T. U. per pound as established by the bidder; or as in the City of Chicago specifications, the number of B. T. U. for one cent, obtained from the bidder's proximate analysis of the coal he proposes to furnish as follows:

$$\text{C. B. T. U.} = \frac{\text{B. T. U. Dry Coal x \% Dry Coal x 2,000}}{\text{Bidder's Price Per Ton in c.} + (.5 \text{ x \% ash})}$$

Determination of Price.—The determination of price to be paid for coal purchased on the B. T. U. basis is a very simple matter after analysis is known, but of course must follow the provisions in the specifications under which the contract is executed. Again consider for illustration the two typical specifications: that of the government and that of the City of Chicago. Price adjustment, government specifications, is made as follows:

$$\frac{\text{B. T. U. in coal as received x bid price}}{\text{B. T. U. established by contractor}} = \text{Price adjusted for B.T.U.}$$

This price is then subject to further adjustment, up or down, depending upon the percentage of ash found in coal in accordance with a table.

Price adjustment on City of Chicago specifications is made in one formula, as follows:

$$\text{Price} = \frac{\text{B. T. U. Dry Coal x \% Dry Coal x 2,000}}{\text{C. B. T. U.}}$$

$$-\,0.5 \text{ x \% ash (as cts.)}$$

Formulæ as simple as these may be prepared to conform with terms of any specifications.

Sampling.—The operators in general are not in favor of selling their coal on the B. T. U. basis. Why? I have talked with operators of mines whose output is of high quality and who should receive a comparatively good price per ton for their coal if sold in accordance with heat value, and with numerous jobbers and dealers, and all seem to object to the B. T. U. method of purchasing coal because of their fear of the sampling of the coal. It is a fact that the securing of proper samples for analysis is the most difficult part of the entire operation. There have been rules established governing the taking of samples which are explicit enough, and if strictly followed would result in fair samples being taken, yet it is easy for the sampler to be careless or even dishonest with results in favor of either contractor or purchaser. A careful selection of samplers of intelligence and unquestioned integrity is the best safeguard for both parties.

The fundamental rule governing the taking of samples is that they shall be fairly representative of the entire lot of coal. Much has been written about the proper method of obtaining and dividing such representative samples. The latest bulletin on the subject is technical paper No. 133, published by the Bureau of Mines and prepared by George S. Pope. This paper very fully describes and illustrates the proper method of sampling coal, whether delivered by wagon, car or ship load. When it is considered that a pile of coal consists of a mass of lump, bone, slack and earthly matter and that the fine coal contains a higher percentage of impurities or ash than does the large lump, the difficulty in obtaining a representative sample may be appreciated. The larger the sample, of course, the less will be the percentage of error, and the sample would have to be larger in coal of lump size than it would be in screenings or small nut. Even in careful sampling there will be some error in individual lots, but with honest, conscientious samplers this error will be practically eliminated through the law of averages where a number of lots on same contract are sampled and results averaged.

Failure to Comply with Specifications.—If the contractor is making a good profit on his contract little trouble need be expected. It may be, however, that a contractor will lose money, and unless he is an honorable contractor with sufficient means to carry him through, trouble may then be expected. The specifications should be very specific as to under what conditions the purchaser has the right to reject a delivery of coal and under what conditions there may be a forfeiture of the contract. The specifications also should provide under what conditions the purchaser has the right to obtain coal from a dealer other than the one with whom he has the contract, and charge the difference in cost, if any, against the contractor's account. Controversy may arise during the life of any contract, and it has been my experience that the purchaser's rights on these points should be strictly guarded. Contracts should be prepared with teeth in them so they will be effective and not merely scraps of paper.

No institution should place its contract for coal with a concern that has previously failed to meet its obligations or has not the means or facilities to properly carry out the contract under adverse circumstances. This is a precaution that should be taken to insure against future trouble.

Conclusion.—Throughout this paper I have attempted to bring out some of the more essential features which should be covered in a specification for coal to be purchased on a heat value basis without going into the details of phraseology and clauses, and have noted some of the advantages of purchasing coal on the specification basis. These advantages cannot be summarized better than they are in six paragraphs of the Bureau of Mines Bulletin No. 41, known to everyone that has made a study of the purchase of coal in this manner. They are as follows:

1. Bidders are placed on a strictly competitive basis as regards quality as well as price. This simplifies the selection of the most desirable bid and minimizes controversy and criticism in making awards.

2. The field for the purchaser and the seller is broadened, as trade names are ignored and comparatively unknown coals offered by responsible bidders may be accepted without detriment.

3. The purchaser is insured against the delivery of poor and dirty coal and is saved from disputes arising from condemnation based on visual inspection.

4. It is not always expedient to reject poor coal because of difficulty, delay and cost of removal. On the B. T. U. system rejectable coal may be accepted at a reduced price.

5. A definite basis for the cancellation of the contract is provided.

6. Being paid for on the quality basis incites the contractor to prepare coal more carefully.

The writer has had nearly ten years' experience in the purchase of coal and has made purchases on all the different methods. Based upon this experience he is convinced that public institutions at least should purchase their coal on the B. T. U. basis as outlined herein until some better scientific method may be developed that will provide protection for both buyer and seller.

Purchase of Coal on Specifications (*Continued*)

By Edward H. Taylor,
Engineer, Crerar-Clinch & Co.

I HAVE been requested to present the objections which coal producers and distributors have to coal contracts containing heat value specifications. I have discussed this subject at considerable length with both operators and distributors, and will endeavor to present a composite picture of their views rather than my own opinion on the matter.

The coal operator and distributor, whom I will refer to as the contractor, have the following objections to heat value specifications as used in coal contracts by public institutions and private concerns today. We will not attempt at this time to give our objections to others than this feature.

1. That the contracts as drawn are not mutual.

2. That the terms of settlement are based on the assumption that all samples taken are truly representative of the quality of the coal delivered. This we contend is not a fact.

3. That the contracts so operate that the deductions made for the delivery of coal below contract grade is greater than the loss actually sustained, making such deductions, therefore, a penalty instead of liquidated damages.

4. That it offers an opportunity for graft and shakedowns on the part of the buyer's representative, and the same opportunity for bribery and trickery on the part of the contractor.

5. That it promotes and fosters unfair competition which works to the detriment of both the buyer and the contractor.

I shall endeavor to make clear the contractors' reasons for these objections, citing some of their experiences.

Objection No. 1.—That the contracts as drawn are not mutual.

For the purpose of illustration we will discuss the heat value specification features of the present state contract upon which contractors were asked to bid last July. We desire that such criticism as we may offer shall be accepted in a spirit of constructiveness, and that we have no intention of conveying the impression that we are in any way aggrieved at the manner in which we have been treated by the state officials who had this matter in charge.

Let us suppose that a contractor offered the state officials a contract containing the same heat value specifications as are embodied in the present state contract, with the exception that the contractor, through his agent, would collect the samples, see that they were promptly analyzed and that the container of the sample, after being filled, was not heated above a temperature of 80 degrees before analyzing, and that the analysis of the sample should be made in the contractors' laboratory, which was to be properly equipped for coal analysis; and that the state should pay the con-

tractor for all coal received the delivered value as determined by his analysis. We hardly believe the state officials would entertain a proposition of this kind even if we assured them that the work would be done only by high-grade technical men.

The state, in their specifications, propose diametrically the opposite, with the exception that they do not assure us that the samples will be taken by technical men, or that the samples will be kept cool and promptly analyzed.

It appears to us that the proposition of the state is just as one-sided as the proposition we proposed, and therefore a contract drawn along these lines could not be considered entirely mutual.

It would not be inappropriate, at this time, to ask the following question: Why not have the samples taken and analyzed by a third party who would be disinterested? This would not be feasible for many reasons, as the sample-taking would require only a small part of a man's time; he would be idle the remainder, for it would be impossible for him to take samples at more than one plant. The cost of sample-taking under such conditions would be prohibitive and there would still be no guarantee that the work would be done more satisfactorily than if performed by a representative of the state or contractor.

Objection No. 2.—That the terms of settlement are based on the assumption that all samples taken are truly representative of the quality of the coal delivered. This we contend is not a fact.

The entire value of heat value specifications depends upon the accuracy and frequency with which such samples are taken and analyzed. The opportunity for error is so great that even an experienced technical sample-taker cannot sample a car of coal twice and get exactly the same results. Therefore, when so much depends upon the human equation you can imagine the results that would be obtained when samples are taken by less experienced and uneducated men, to say nothing of samples taken by men who may be prejudiced or dishonest.

One contractor contributes the following on this subect: "Section 21 of the state specification provides that samples of from 75 to 100 pounds are to be taken from each car, and assumes that the sample is exactly representative of the average quality of the coal in the car. This assumption is a fundamental error. It is rare indeed that two gross samples of the same shipment can be taken, handled independently and give the same money settlement in the final result. This is true when the work is done by high-grade help who thoroughly understand the importance of the several operations, and conscientiously endeavor to follow a standard of procedure. Many samples are gathered by labor that have no conception of what it is all about, and whose sole purpose is to get through with the task as easily as possible. The results obtained are often very radical. The errors made in favor of the contractor will not cancel the errors against the contractor even after twenty or more samples have been gathered and analyses

made. In the past, some of the specifications for state institutions have been very elaborate in their description of how the samples should be prepared. This did not result in satisfactory sampling. We had the experience of having one analysis reported several weeks after the entire shipment had been consumed, showing a penalty of 35 cents per ton. The coal shipped was from our own mine in the Southern Illinois field. The analysis reported was a typical analysis for Central Illinois coal. Under the specifications the contractor had no recourse but to accept the unjust penalty. At another time, a large sulphur ball was included in a sample of about 100 pounds, the sulphur ball weighing about 18 pounds. Upon questioning the chief engineer, he stated that the sulphur ball had been caught by chance and therefore had been placed in the final sample. Careful search over 10,000 square feet of coal of the pile and repeatedly digging into the pile failed to find even one small sulphur ball. Yet this chief engineer was including enough impurity to cause a deduction of possibly 15 cents per ton. At another institution the coal was being prepared by the method of quartering. The man doing this work went from the shed into the yard at frequent intervals to attend to other work. Each time he returned to the shed he carried in considerable mud on his shoes, which was kicked off on the floor and found its way into the sample."

It is inaccuracies such as these against which the contractor has no protection that makes him skeptical about accepting such contracts.

Sample grinding machines are supposed to overcome some of these troubles. However, the analysis of two cans of the same sample, prepared by one of these grinding machines, in the commercial application of them, showed a variation of practically 4 per cent in the settlement price; yet the coal of these two cans was supposed to be identical in character.

If the coal sampled were lump, egg and mine run, the chances for inaccuracy are even greater than when screenings are sampled. I once took three samples from a car of mine run and had a variation in the dry ash content of the three cans from two to six per cent. The errors and prejudice which enter into sample-taking invariably work an injustice to the contractor. I will mention several concrete cases which have come under my personal observation.

Case 1. A government plant sampled 50 cars of 1½-inch screenings and reported 19 per cent dry ash content. The coal was from a good mine in Southern Illinois. The operator sent me to the plant to make an investigation. The entire 50 cars of coal had been consumed. The plant was equipped with chain grate stokers, a coal weighing device and a Venturi meter. The engineer was competent and unprejudiced. He kept a very good log of his boiler room operations, and had nothing to do with the taking of coal samples and knew nothing of the results obtained, that matter being in the hands of the Quartermaster's Department. The engineer showed me his log. The evaporation, boiler and fur-

nace efficiency had been fairly uniform for the previous three months. His cost of making 1,000 pounds of steam had remained practically the same, as it had been computed on the contract price and not the delivered value. The period for which I had examined his log showed that the plant was consuming about 50 tons of coal per day, and covered the time when the 50 cars of coal alleged to contain a dry ash content of 19 per cent had been consumed. There was nothing in his records to show that he had been using an inferior grade of coal during that period, although the Quartermaster's Department had deducted over $900 on account of excessive ash in the 50 cars above mentioned. The engineer, at my request, showed me the ash-pile, which fortunately had been cleared up, according to his records, 60 days previously, and contained only the ashes from the 50 cars of coal in question and about ten additional cars.

We weighed up a cubic yard of the ashes, which were extremely wet, as they were exposed to the weather, the investigation being made in the month of November. We then measured up the ash-pile and found that by weight there was less ash and water in the pile by over 20 per cent, although it contained the ashes from 60 cars of coal, than was supposed to have been in the 50 cars for which the operator had been docked for over $900, on account of excessive ash content. I gave the engineer the government report showing the amount that had been deducted. He smiled and said: "See the quartermaster; it is up to him to explain." I did as the engineer suggested. The quartermaster was a West Point graduate of many years' experience in the army. He went over the log with me very carefully, examined the ash-pile, checking our weights and measurements, and said nothing. He undoubtedly saw the point. He invited me to lunch at the officers' mess and, after luncheon, informed me politely that the "Army never was wrong." I dropped the matter. The next 50 cars delivered contained an average of 7 per cent ash; the following 50 cars about 8 per cent. The operator got his money back and then some more. I was willing to admit the "Army never was wrong." It paid in this case to do so, although we were all aware that 1½-inch screenings from this mine in the Southern Illinois field never were produced with an ash content as low as 7 or 8 per cent or an ash content as high as 19 per cent. What is the value of a B. T. U contract when it works like that?

Case 2. One of the large public utility companies operating a number of plants sampled and analyzed the coal which they received daily. One of their plants using 400 tons per day reported car after car of 1½-inch screenings coming from a certain mine in the Southern Illinois field as having an ash content of 20 to 40 per cent. Still their pounds of coal per K. W. of output, according to their log, remained the same. The vice-president of the company arbitrarily made a large deduction on account of the excessive ash in the coal delivered to this particular plant. An investigation proved that the engineer did the sampling himself,

thought the coal was all dirt, sampled it according to his prejudices, and acquired an extreme dislike for the coal contractor. The same company, at another plant using 600 tons of coal per day, received 1½-inch screenings from the same mine, the two plants practically dividing the output of the mine. The samples taken at this second plant showed a dry ash content in the coal of from 12 to 15 per cent, and the coal consumed per K. W. of output is about the same as the first mentioned plant. When these facts were submitted to the vice-president of the corporation he dropped his claim for a reduction of price on account of poor coal.

Case 3. A private corporation hired an outside engineering firm to handle a heat value specification contract. Ten cars of coal were shipped to each of three plants. A record was kept of the evaporation and efficiency of the plant and each car of coal was sampled and analyzed,—an average of the analyses obtained on the thirty cars to be used as a basis of the contract. The first month the delivered value varied but slightly from the contract price. The second month a deduction of from ten to fifteen cents per ton was made in the delivered value, although the ash and moisture content of the coal delivered, as shown by the analyses, was practically the same as the contract; but the B. T. U. was from two to three hundred less on each sample analyzed. Upon investigation it was found that samples had been held at the plant until the end of the month, and had been kept in the engine-room, which was extremely warm. When the sample cans were opened, the hydrogen and methane gas escaped; therefore the B. T. U. did not come up to the standard of contract. When this matter was brought to the attention of the company and evidence submitted proving what had taken place, the analyses for that month were ignored, and the company paid the contract price for their coal.

It may be of interest to state that Professor Parr, of the University of Illinois, some years ago discovered the fact that samples held for any length of time deteriorated very rapidly. This points out quite clearly the care that must be observed in handling samples after the same have been taken. Otherwise it gives another opportunity for inaccuracy which mitigates against the contractor.

Case 4. This story was told me by the head of an engineering company who specializes in coal analysis and heat value contracts. He said that he started out to check up one of his sample-takers, and saw the sample-taker take a sample from a pile of egg coal. The sample-taker took two shovels full of the fine coal and started to quarter the same down, before he discovered that his boss was watching him. The sample-taker intended to save one-half hour's work in a hot boiler-room, but lost his job instead. If he had not been detected the contractor undoubtedly would have been docked unfairly. Is it to be wondered at that contractors, who have had their fingers burned, dread the fire?

Another opportunity for errors occurs in the laboratory. Unfortunately, many laboratories are not properly equipped to make

fuel analyses, especially B. T. U. determinations. In order that B. T. U. determinations may be made correctly, it must be done in an oxygen bomb calorimeter, equipped with a Beckman differential thermometer, standardized by the Bureau of Standards, the water equivalent of the calorimeter being figured on some substance such as benzoic acid, naphthaline or cane sugar, previously standardized by the Bureau of Standards, using the specific heat value of the same as determined by them. It is a well-known fact that many laboratories are not equipped in this manner, but still make B. T. U. determinations, and want contractors to settle on figures made from their determinations.

Objection No. 3.—That the contracts so operate that the deductions made for the delivery of coal below contract grade is greater than the loss actually sustained, making such deductions therefore a penalty instead of liquidating damages.

For the purpose of explaining this objection we will assume that the samples taken are truly representative of the quality of the coal delivered. We will assume a state institution made a contract on 2-inch screenings from Southern Illinois. The contract data, being moisture 8.5 per cent, ash as delivered 12 per cent, dry B. T. U. 12.500—price $4. Net B. T. U. for 1c. 55,520. Assuming the plant to be in good condition probably a boiler and furnace efficiency of 70 per cent could be obtained. That would mean that each pound of contract coal delivered would evaporate from and at 8.24 pounds of water per pound of coal. Assuming the plant consumed 3,000 tons per month, and the analysis for the month's delivery showed the following quality delivered: Moisture, 9.5 per cent; ash, 13 per cent; dry B. T. U., 12.340. Delivered value $3.8730 or $0.1070 below the contract price, or a total deduction on the month's delivery of $321. Did the institution sustain that much loss? Coal of the analysis as delivered would, at 70 per cent boiler and furnace efficiency, evaporate from and at 8.07 pounds of water per pound of coal. I do not believe that anyone would claim that an increase of 1 per cent moisture and ash would change the efficiency of the plant. If coal worth $4 per ton, as contracted for, would evaporate from and at 8.25 pounds of water per pound of coal, what is coal worth that will only evaporate from and at 8.07? My figures show $3.9126, but the state contract would deduct $3.8930, or $0.0196 per ton more than their actual loss. This would take $58.80 of the contractor's money unlawfully. If the sampling had been in error the contractor would have lost the whole $321 unlawfully.

The city of Chicago at one time attempted to operate a contract which prescribed a penalty for the delivery of coal below contract grade. At the expiration of the contract the several contractors who had delivered the coal sued the city and obtained judgments against the city for the amounts deducted on the grounds that they were penalties, not liquidated damages. Liquidated damages can only be collected where the damages sustained can be proven.

There are many different forms of heat value contracts that contractors have been asked to bid upon and accept. Over twenty different kinds have come under my observation. None of them were as fair and equitable as the form of the present state contract, to which the contractors find the objections enumerated. The defects in the other forms of heat value specifications were principally these: that they were not mutual—that the buyer endeavored to collect a penalty on all coal delivered below contract grade instead of trying to collect liquidated damages. One contract even deducted 3c. a ton for each one-half of one per cent of sulphur in excess of contract grade. Another, after deducting for B. T. U., deducted 3c. for each per cent of ash above contract grade, and none of them paid a bonus in the same proportion for coal above contract grade. Some were based on evaporation tests.

Objection No. 4.—Offers an opportunity for graft and shakedowns on the part of the buyer's representative and the same opportunity for bribery and trickery on the part of the contractor.

Sections 24 and 25 of the present state contract offer a great opportunity to take care of a favored political contractor or shake down an enemy. This has been done in the past by the representatives of both public institutions and private corporations. It also offers a great opportunity for an unscrupulous contractor to bribe the buyer's representative. You all know the salaries of men in such positions and the frailty of human nature. It seems unnecessary to take time to mention specific cases. Many are a matter of court record.

Objection No. 5.—Promotes and fosters unfair competition which works to the detriment of both the buyer and the contractor.

Every industry has men engaged in it who are tricksters and whose methods will not stand investigation. This is no reflection on the industry. The great majority of coal operators and distributors in the state of Illinois today are broad gauged, fair-minded, honest men who would be only too glad to rid their industry of the undesirables. The heat value specification offers a golden opportunity to the trickster. If he so chooses, and he usually does, he alone can make honest competition impossible on any heat value contract. The way the trickster operates is to submit a bid on a higher quality of coal than he is able to produce. He does this in order to get the business. If he has political pull it is easy. If not, he makes it appear to the buyer that he is cutting the price. This may look good to the buyer, but is it to his advantage? Is the price-cutter an asset or a liability? If a man is getting his price he will deliver the goods and go about his business. If he has taken the job too cheaply, either by accident or intent, he begins studying how to beat the game, and the man who is a trickster can generally find a way.

I know of a case where a very high B. T. U. was bid by a contractor. He obtained the contract. The delivered value on the coal delivered was invariably above the contract price. The operating cost to the boiler-room increased. The engineer's suspicions

were aroused. He could not understand how he was being stung. The analysis of the coal showed it to be of good quality. Yet the engineer could not get results. Finally he discovered that one of his own trusted employes, who was taking the samples of the coal as delivered, was a relative of the man who was the contractor. Possibly this sample-taker was a little prejudiced in favor of the contractor. Maybe the contractor knew this and made his bid accordingly. I would not say that the sample-taker was corrupt, because I have no definite knowledge on the subject, but I can say he was promptly discharged when the engineer found out his relationship to the contractor.

It is the desire of the reputable contractor to give the buyer a square deal, and the buyer should show a disposition to do the same. The contractors have many troubles to contend with, such as working conditions at the mine, car supply, etc. Many times the buyer does not understand these conditions and misjudges the intent of the man with whom he is dealing. This is wrong, but cannot be corrected by purchasing coal on a heat value basis, or by trying to sting the next coal operator with whom the buyer deals. The buyer must pay for what he gets, and if he starts out to sting the contractor, the contractor must protect himself and is very liable to give the buyer the worst of it.

While the proposition of purchasing coal either for public or private institutions is a most serious one, and the buyer should be accorded every protection possible, at the same time he should not, while endeavoring to protect himself, invite his own employes to become grafters, and his contractor a bribe-giver. This he is almost sure to do if he so frames up a contract that it is not fair and equitable. What we need is a closer relationship and more confidence between the buyer and the contractor.

The coal operators and distributors were requested to present their objections to heat value specifications. This they have attempted to do; but, with your permission, we shall take the liberty of suggesting something constructive along the line of coal contracts. Unless we do this, we feel we may be considered reactionaries.

The contractor fully realizes the value of the proximate analysis. He uses it himself when he sinks a mine. He causes samples taken from drill cores to be analyzed, and from these determinations he decides whether the quality of the coal is worth mining. The contractor also believes that the proximate analysis is valuable for the purposes of identification. He uses it for that purpose. The proximate analysis and sample-taking are sufficiently accurate for this work.

The contractor believes the buyer should select the coal best suited to his needs, after having tested the same in his plant to his own satisfaction, and then ask for bids on the grade of coal desired—not for bids on any kind of coal. The Retail Coal Merchants' Association of Chicago are now working on a plan of grading the various kinds of coal, with regard to quality, that come into this market—each grade to be designated by a letter, and

the quality of the coal as shown by proximate analysis to come within the limitations prescribed for each grade. If the buyer and contractor could coöperate on this proposition, I believe that a satisfactory grading of coal can be effected. so that a buyer may ask for bids on grade "A," "B" or "C," as may be desired. The buyer, after receiving his bids, should contract for his coal F. O. B. mines, paying the freight and getting the freight bills, which will prove that he is getting the coal which he purchased. Some public institutions and private concerns ask that the contractor pay the freight. This is unfair, as it frequently ties up a large sum of money—some public institutions having been known to hold up their bills for three and four months. The buyer, by purchasing coal under a contract of this kind, which should contain a paragraph giving them the right to reject any coal that is not in conformity to the grade purchased, receives the best protection possible, as the coal operator cannot change the quality of his product at will, as some buyers seem to believe. If the buyer is unfortunate or foolish enough to deal with a price-cutting trickster, who may attempt to deliver coal from some other mine, or of some other grade than the buyer purchased, he is protected from this abuse by his freight bills or bills of lading which definitely determine the origin of the coal. I have frequently purchased coal in this manner, and the results have been uniformly satisfactory.

The question now arises, how shall the buyer of wagon-delivered coal be protected? The buyer should determine the grade of coal desired and so specify in his contract, reserving the right to reject any coal not coming up to contract grade. If he is dealing with a reputable contractor, he will have no trouble. If he deals with a price-cutting trickster, he must keep his eyes open both day and night. He should have his coal analyzed and see if it is conforming to the grade purchased; if not, he should reject it and order the contractor to remove it. This is seldom done, because the contactor offers to sell his coal at a reduced price rather than to remove it. The buyer makes a mistake when he accepts the coal. First, because a reputable contractor becomes suspicious of a buyer who rejects coal and then accepts it at a lower price, feeling that it is a shakedown. If the buyer orders the coal removed, he punishes the contractor in a way that the contractor dreads the most.

The order to remove coal of inferior grade is the big stick in the buyer's hands, if he but only knew it. I say this with confidence, as I once made a contractor remove 500 tons of Pocahontas coal, which was below grade. It was done under a contract made along the lines suggested. The contractor begged that I rescind the order and offered me the coal at 50 per cent reduction. I stood firm and made him remove the coal. The lesson taught him to respect me forever afterwards and I never had any more trouble with him. A trickster, when he is cornered, will be good, if he can't find a way to bribe himself out. If you make him remove his coal, he can't bribe anyone.

DISCUSSION.

Mr. Postel. In presenting these papers I wish to say that to those of us at least who are interested in the purchase of coal in considerable quantities, the question of purchasing on specification is a most important one. This is especially true where the purchasing is done on public contracts. There is a sharp distinction between purchasing on public contracts and on private contracts. In the case of a private contract the purchaser has the privilege, and exercises it, of restricting the bidding to those firms that he has confidence in. In the case of public contracts the bidding is thrown wide open to the responsible and the irresponsible bidder alike. There are certain safeguards, but nevertheless it is a fact that in all public bidding anybody, almost, can bid and often does bid. I believe that the most earnest advocate of the system of buying on specification will admit that it has its drawbacks; but he will probably argue that he hasn't found any substitute that is any better. Theoretically, the plan is an ideal one. In the first place it enables you to express the difference in qualities of coal in terms of dollars and cents. In the second place, theoretically, at least, the purchaser pays and the seller receives, pay for what he delivers. When we get to the practical end of it, however, we must all admit there are very serious drawbacks in carrying out the plan, and you have had an opportunity tonight to have these drawbacks discussed from the standpoint both of the purchaser of the coal and the seller of the coal. The object of the meeting is primarily to bring out a discussion which might be the means of leading to a better understanding as to the method most satisfactory, both to the purchaser and the seller, for the purchase of coal in considerable quantities, and I hope that you will all feel free to enter into the discussion fully, and give us the benefit of any suggestions you may care to offer.

Mr. Vial: There is one feature that hasn't been discussed in contracts for public institutions or public buying that do not appeal to the operator. Public business is almost universally let on the price basis only, regardless of the service a company may have rendered, or the quality of coal or their reputation for sterling honesty, and if a contractor takes care of his contracts, even beyond the literal provision of the contract, to possibly a serious financial loss to himself, the next time a contract comes up he has no assurance that he has any chance at all to land the business, as any sharp competitor that can under-bid him a fraction of a cent is certain to get the business. That is one of the features that makes public business not attractive as ordinary commercial contracts, where the one placing the business, the purchasing agent, has more opportunity to exercise his personal judgment.

A serious error is often made in the present B. T. U. contracts on this score of composite samples. We have all more or less become familiar with the results that can be had in B. T. U. determinations in boiler tests where we are running acceptance

of boiler and furnace tests. In a case of that character we have two, three, or more experts watching details and very carefully preparing the gross samples, which are finally worked down to a laboratory sample and analyzed, and in general the work checks fairly well, but in the commercial operation of B. T. U. contracts we don't have anywhere near that careful checking. Usually the work is done by some employe that is more or less careless, simply his job has been assigned to him and he wants to get it done. We will assume that various samples have been gathered to represent different shipments and we will assume that in that shipment maybe there is one car that is really off—decidedly off grade. It is apparent indeed that when possibly ten samples of composite are mixed that that one bad car and the nine good ones will get the proper proportion in the final sample that goes to the laboratory, and because coal inherently has a minimum amount of ash and moisture and a maximum amount of B. T. U.'s under ordinary conditions, there is a certain point beyond which the contractor cannot go in delivering desirable goods; but there is no limit in reducing the quality by adding ash and other impurities. For that reason it is very seldom and rare that the laboratory report will, in just ordinary business chances, favor the contractor. Nine times out of ten, even in honest cases, the error is against the contractor.

Many B. T. U. specifications are so worded that if there is a variation of one B. T. U. or one fraction of one per cent in moisture, or ash, or B. T. U. from that guarantee, then there is a corresponding change in the settlement price. This provision is a hair-splitting technicality. In general the laboratory considers that it has done satisfactory work if it checks moisture, or ash, or B. T. U. by one-half of one per cent. In other words, the laboratory report may vary settlement price approximately one per cent, and from the chemist's viewpoint he has done satisfactory work. Graphic tabulation of the results of many analyses from coal from the same mine indicate that a variation of three to four per cent from the average is experienced in commercial working of B. T. U. specifications; it would, therefore, seem advisable in case of a B. T. U. contract, that if the contractor were to deliver coal—I will break in there. Now these three or four per cent variations seem to be in the commercial working of a contract the minimum and maximum that can be reached, assuming the actual average values of the coal. Many of the reports will vary considerably from that actual average, as much as three or four per cent, frequently beyond three or four per cent will occur, but they stand out so prominently on a graphic chart that they don't come within the general results. But the general results will vary three or four per cent from the actual average, and yet the contractor is penalized for a theoretical variation of one B. T. U. If a contractor were to make his guarantee such that he would escape penalties, the analysis guaranteed would be so low that his competitors would have material to use in arguing that his coal was of poor quality and offer his guarantee as evidence.

One year our company shipped coal to two different groups of institutions under so-called B. T. U. contracts. That is, these institutions were in different states. Shipments were from the same mine. The product of this mine and neighboring mines has a wide reputation for high quality. The average of scores of reports by each laboratory for the year's business covering several hundred carloads did not check by approximately four per cent. Since there were more than nine hundred carloads involved, it is reasonable to assume that the coal received by the two different groups of institutions was of the same average quality. I showed those charts to Prof. Parr, and all the comment that I could get from the professor was a shrug of the shoulders and the statement, "It looks to me that the state institutions should standardize their price."

All this hair-splitting of buying coal on a B. T. U. basis in some respects is amusing, for there are astonishingly few plants that attempt to buy the coal on a B. T. U. basis that have any way of knowing what returns they are getting from the coal. They do not know whether they are evaporating three pounds or ten pounds of water per pound of coal. Practically no consideration is given to the adaptability of fuel for a given set of plant conditions, except that of size of the coal. Merely because a bid happens to figure the greatest number of B. T. U.'s for one cent is no assurance that in actual operation the coal offered is the cheapest for conditions under which it is to be used. If plants that buy coal under B. T. U. specifications could determine from the cost of steam to them the relative value of different coals, they would then have the most reliable means of determining the merit of different coals offered.

There are a few other points in regard to coal specifications that might be mentioned. In case a buyer desires the bidder to submit analysis of the coal bid upon, it would be well to require a bidder to submit a certified copy of an analysis of the coal offered as determined from a recent commercial shipment, giving the name of the laboratory making the analysis. The name of the laboratory is vitally important, as there is considerable variation in the reports submitted. I will merely mention two reasons for these variations.

Some laboratories do not make any sulphur correction when burning coal samples in an oxygen bomb, merely reporting the apparent B. T. U. as the heating value for the fuel. Another error is made by determining the moisture in two steps, known as air drying process. The proper method for determining moisture is to take a separate portion of the sample, say ten grams, that has been crushed to approximately ten mesh screen size, and determine the moisture on this separate sample. The variation in the moisture determined between the method suggested and that by determining the moisture in two steps, first in air drying, then baking, a pulverized sample, will be as much as one per cent for Illinois coals.

Specifications requiring a contractor to quote delivered prices and weights are not attractive to operating shippers, because the contractor cannot afford to have a representative present to receive each individual car as it arrives at destination. When shipments arrive that show loss of coal in transit, often evidence which the shipper can prepare in support of claims for loss is not sufficient, because the consumer failed to take proper steps to protect the shipper. On railroad shipments there should be allowed a variation of one per cent in net weights between destination and mine weights.

In case of greater variation the adjustment should be made on the variation in excess of one per cent. The burden of proof of shortage should be upon the consumer. If destination weights are to be used the buyer should weigh the coal in such a manner that a sworn weight certificate can be furnished the contractor that will be acceptable to the railroads, upon which he can base his claims for shortage. If the customer cannot furnish evidence of destination weight which would be satisfactory to the claim department of the railroad, then it should be assumed that his weights are not accurate or equitable and should not be binding. A case of that kind came up this week. Two cars of coal arrived at destination and the two cars were approximately thirty tons short, according to the reports, but we cannot collect for shortage because of the fact that the evidence as prepared will not be accepted by the railroads. Under the contracts our company has to stand a loss of freight on thirty tons of coal, plus the price of thirty tons of coal.

The original bill of lading is required by the railroad as evidence of ownership when a claimant presents claim for loss in transit. Therefore, only in cases where the consumer is able to handle claims for shortage should the original bill of ladings be delivered. In case destination weights are to govern settlement, and the consumer desires to assure himself as to the origin of shipment, copy of bill of lading could be secured and forwarded. That bill of lading is the consumer's protection as to the source or origin of his coal, but if the operator has to accept destination weights, the operator then has to collect shortages. But the railroads require the original bill of lading to be filed with the claim. When you begin to get into that side of the argument you get into some rather technical legal stuff.

Recent specifications by one buyer provided for using "approximate characteristics of the coal desired," as given in the specifications to determine the settlement price if the buyer did not make analyses of the coal delivered. If the contractor delivered coal better than "approximate characteristics desired," under the specifications he would be penalized. On the other hand, if deliveries were below "approximate characteristics desired," the settlement price would be increased above the price that would be determined by an analysis. If a public institution arranges to buy coal under B. T. U. specifications they should be careful to make analyses with

great regularity, otherwise they are open to charge of sticking their opponents and playing into the hands of favorites.

Occasionally specifications provide that four or five analyses shall be averaged to determine the settlement price for a month's shipment, and if one analysis represents a very small tonnage it has undue influence on the final results. We get into arguments on those. One analysis may represent one carload. Another analysis may represent several carloads. Occasionally we find them taking an arithmetical average of them regardless of the influence on the total shipment as represented by the different analyses.

The clerical work required in handling the details of the so-called B. T. U. contract requires considerable additional work compared with the usual commercial contract. The work of issuing debits, credits and like adjustments and the checking of laboratory reports requires more work than the usual forms of contract, and this extra work becomes a decided annoyance, and unless the contractor receives considerably more than he would under the commercial contract he will feel that he is being imposed upon. My own experience is that a contractor should receive about ten per cent more money on B. T. U. contracts as compared with the price of the usual commercial contract. Under the present industrial conditions in the coal trade, it is probable that some one will bid under the B. T. U. specifications at the general market price instead of adding the extra cost of handling business of this character.

Mr. Howatt referred to the U. S. Government specifications for this last year. There is one clause in these specifications that is at least entertaining. It requires the contractor to quote the moisture content of his coal. They provide a very, very heavy penalty if the moisture exceeds that, and specifically states that there will be nothing paid if the moisture is lower than quoted. In other words, I would assume that from my business experience this contract is not enforcible at law.

There is another feature, a commercial feature, about the buying of coal on the B. T. U. basis. A couple of years ago coal was very, very short. A man came into the office and made an inquiry. He said, "What has happened to the fellow that used to buy the coal on the B. T. U. basis?" He was buying coal running about thirty to forty per cent ash because no one else would sell him, and some one spoke up and said, "He is buying Northern Illinois screenings."

Speaking about commercial plants, Mr. Taylor referred to the Commonwealth Edison Company of Chicago. All of the users of coal buy their coal on what we consider a straight commercial contract, but they all analyze their coal for their own private information, and if there is something about it that is not satisfactory, they call the contractor's attention to it, and being as the contractor wants that business in the future, he takes care of their complaint, and there is no more trouble about it. The only ones that have, in my estimation, any trouble in adjusting their complaints would

be the state institutions and public buyers, who are hemmed about by legal restrictions that are not a handicap to the average commercial buyer.

Mr. Marsh: The city of Chicago commenced buying coal on the B. T. U. basis about ten years ago, and they changed from the evaporation basis at that time because of the fact that on the old evaporation basis the specifications required that the contractor be notified four hours in advance of an evaporation test, and it invariably happened, at least to a majority of our stations, that a considerable amount of extremely good coal was delivered for that test.

Mr. Taylor has mentioned the case in which the city lost a suit because of deductions made from the contractors' bill, and I believe that I recall that case, and also the reason why they won their suit, I believe, outside of the technical or legal questions involved, was that in no case could the city prove that all the valves had been blanked off, and that there was not water going to waste which had not been weighed. We therefore decided that that method was not satisfactory, inasmuch as in this case the deductions amounted to something like, I believe, fifteen thousand dollars, and they have been made, in good faith, I am sure of that, but the city had to pay it, besides all the other expenses that were involved.

We do not claim that the specifications are ideal by any means. We only feel that in the past ten years they have given us a great deal more satisfaction in the purchase of coal for our various stations—and we have quite a good many—than did the other method on which they were purchasing coal before that time.

We have to rely upon men, of course, and upon their integrity, to take care of this. We have been checked up at least three different times, in one case two sets of samples were taken for a period of three months, and the results reported by the city testing laboratory were fairly well borne out. I will say that the samples were taken separately and of course there were no absolute agreements, and if they had agreed closely, I would have thought it was an accident, because, as Mr. Taylor mentions, sampling coal where the impurities vary so in size, and where the effect of impurities is so great in proportion to the coal itself, makes it a difficult matter to obtain absolutely representative samples.

I have recently made a recommendation that we install automatic samplers at our stations where such can be installed. I don't mean by that the grinding machines for reducing samples to a laboratory sample, but some method for automatically taking a sample from the cars every so often after the coal has gone through the crusher, then taking that sample and quartering it down until we get a laboratory sample. I feel that that relieves to a certain extent the personal equation in the matter of samples. I was one that purchased coal on the B. T. U. basis, and of course one who sells it on that basis would be glad to have that equation entirely removed. The samplers are thoroughly instructed in their work as to what they are supposed to do, but when you tell a sampler that he is to get a representative sample from the delivered

coal, you are giving him quite a good sized job. However, in our contracts, and in our deliveries of coal we are sampling every day at every station, and we are combining those daily samples into one weekly sample for laboratory tests. That will run four or five tests during the month for each station. We feel that during the duration of the contract, one year or possibly fifteen months, if an extension is granted, that the tests have pretty fairly represented the delivery of the entire quantity of coal throughout the year. We pay on the monthly basis, of course, for the coal delivered during that month.

I have recently been examining the 1920 government specifications, and I had it in mind to ask Mr. Taylor as to what he thought of the government specifications. One point was brought up which I consider entirely unfair, but, as an illustration of this question of moisture content, I had occasion to personally sample coal about two years ago at a point in the city, coal which was coming in on the day on which the sample was taken, and coming in in a driving rain storm. The contractor himself was at the point of delivery, and he was very much wrought up over the fact that he would be compelled to stand for the moisture in that coal. By no argument could I convince him that the coal was weighing much more, so I didn't think he was going to lose a whole lot, but as a matter of fact the delivery in question was soaking up a lot of water, and there was no reason why this particular party should pay for all that water at the price per ton that he was paying for coal.

The question about the storage of samples was brought up, and it hasn't come to my notice that there has been any great variation in the storage of samples, so far as we keep them. We keep all our samples for a period of three months after the test has been reported. That is merely to help out in the case of any controversy over the tests, and for the purpose of checking up later on if controversy arises. But in the storage of the samples as they come in we have a sealed can, and I wish someone that has had experience would tell me how to seal a can so it is absolutely sealed, and do it quickly and expeditiously on the job, when the man is sampling. I have never found a way yet that is satisfactory to us. We have used special paste for labels and stickers on top of the cans and all that, but we find that every now and then a can will be discovered in the storage room that the labels have all come off, and it isn't sealed, but usually they are so old that we don't have to worry about any question connected with those samples. As I say, we purchase a very great quantity of coal, and I am under the impression that the city of Chicago cannot very well purchase coal except on some guaranteed basis that will enable us to check up on deliveries, and a portion of the government specifications have appealed to me somewhat, inasmuch as it does not provide for a B. T. U. deduction unless the variation is greater than 200 B. T. U. It also has a sliding scale for ash deductions, and I heartily approve of that. Originally the proper

deduction which we made for ash, and which was included in our specifications, was made on the assumption that it costs about fifty cents a ton for the removal of ashes. It costs the city of Chicago a lot more than that, except in some few cases where we have been fortunate enough to sell some of the ashes, but those cases are very far between. Where we get deliveries of coal with ash running a great deal higher than the guarantee, that deduction is not sufficient. I would like to see a specification, however, that could be considered fair and acceptable both to the purchaser and the contractors.

So far as troubles concerning contracts of the city are concerned, I believe that the greatest trouble has been, in the past anyway, with the contractors over-bidding themselves, and, as Mr. Taylor brought out, possibly with the idea of obtaining the contract in the first place. To avoid that trouble to some extent, a year ago we placed maximum B. T. U. limits, so far as figuring the price is concerned. That was to prevent the contractor bidding way above what his coal possibly could reach, just in order to secure the contract, and then causing us a lot of trouble throughout the year by controversies and all the time complaining that he was not getting a fair deal. The largest amount of money ever deducted, I believe, on a B. T. U. basis, covering a year on our entire basis of coal bought, was something like seven thousand dollars on about five hundred thousand dollars' worth of coal. We are paying occasionally a bonus. I have a case in mind at the present time where a contractor started to deliver a very good quality of coal. It was well up to his guarantee and entirely satisfactory to the engineer, but within a couple of months the quality of the coal dropped so much that deductions amounted to quite a considerable amount. Upon investigation we found that the deductions were entirely fair. In fact, judging from the use of the coal, the variation in size, etc., the deductions could have been much more without being at all unfair, and in a case of that kind, while the plant engineer may have objected to the coal as not being up to the specifications, had we no method for determining whether it was or not, we would have stood to lose, and the result has been that by testing and sampling, we have gotten the coal back to a point where it is again satisfactory. Whether this was intentional switching of coal or anything of that kind, I don't know, but speaking from the standpoint of the city, we are compelled by law to purchase materials under certain requirements which prevent our going into the market and purchasing as a private consumer would be able to. We are compelled by law to settle in accordance with certain legal requirements. After ten years' experience with the city I can say that at least up to the present time there has been no way that will give us the service and the satisfaction that we have had.

Mr. Langtry: Mr. Taylor taught me the business. I started out a number of years ago to sample coal. That was one of my first jobs. I found then that the sampling of coal was one of the

most important, if not the most important, thing in buying coal upon the B. T. U. basis. You could fluctuate the analysis by the sample that you took. Therefore, the sampling of coal should be in the hands of people who are experienced in knowing how to do it. The purchase of coal upon the B. T. U. basis should not be placed in the hands of people who have not had experience in doing the work, and it has been my experience in the past that there has been the source of most of the trouble. Coal companies have been at fault, consumers have been at fault. Coal companies have over-bid themselves. I had a very striking example in Milwaukee. I was called in on a dispute that was very, very bitter. There were thousands of dollars involved. Cargoes of coal were arriving up here and the delivered value of the coal was away down below the quotation. I sampled a number of cargoes going through and took the samples and analyzed them, and found that the analyses all checked fairly closely. My recollection is they checked within two per cent. After this work was done the shipper of the coal was called in on the conference, and I asked him how he arrived at the figures that were submitted in his coal contract. He said, "We went right down into our mine; we took a sample right off the face of the vein." I said, "That sample off the face of the vein I suppose ran about two or three per cent less than this mine run is running, didn't it?" And he said, "Yes, it did." "And that is what our coal is like." He didn't take into consideration that the miners in the natural course of mining probably got up some of the floor, the bottom of the mine, and also some of the roof; consequently he thought that he was being penalized by sampling that wasn't done right, by analyses that weren't performed right, where he was really at fault himself. It has been my experience that a lot of this trouble has been occasioned by coal operators themselves over-bidding themselves, thinking that they can get by. Their greatest inclination in submitting propositions is to submit the maximum figures instead of taking the average.

There have been many contracts that I have thrown out, so to speak, that have been submitted to consumers for the reason that I knew before they went into it that the coal contractor was going to get stung, simply because he was bidding way beyond what his coal would actually produce. It seems to me that the purchase of coal upon the B. T. U. basis should be looked upon in a little different manner than what it has been in the past. I realize that public institutions are handicapped, and it is really doing the purchase of coal in this manner an injustice to speak principally about public institutions, because they are handicapped. There is no question about it. The funds are limited for the supplying of the necessary help to do the work, and do it right. At least that has been my experience. I have gone around representing coal operators to the different public institutions throughout the state and have found conditions that were abominable—a man taking a sample of coal and putting it into a wheel-barrow half loaded with ash, the same wheel-barrow that he had been wheeling the

ashes out in. That was doing the coal operator an injustice. The institutions were limited, didn't have the men, and couldn't do the work right. But you take private institutions who will buy their coal upon the B. T. U. basis and do it right, and it is one of the easiest way to make their purchases and make adjustments.

For instance, this last spring there was a consumer of coal down in Indiana who had been using a certain grade of coal from a certain mine. There was another coal from the same seam that happened to be better. I knew about it and I suggested to this operator to try this coal. He ordered fifteen cars, put it into his plant, and the next word that I received was that the coal shut their plant down. It absolutely was worthless in their plant. I knew that that coal would not shut the plant down because it was a better grade of the same kind of coal, the same characteristics that he had been using in the past, and I knew there was some other condition there that was causing this trouble. The engineer went down and made an investigation of the plant and found out that the plant had their heat bottled up, so to speak, in their furnace, and this coal was so hot that it burnt his grates and melted his brick work, and the result was that he couldn't utilize the heat from the coal. Therefore, that consumer was doing the operator an injustice because his plant was not in condition that it should have been to burn a good grade of coal.

If you will apply the burning of coal on the B. T. U. basis in the right way, if you will take coals from a certain district, from a certain seam, and make honest comparisons of this coal, get an analysis that is really representative of this coal—and you can get samples and have an analysis that does really represent the quality of the coal—if you will make comparisons in that way and reduce this quality of coal to some comparative figure in which you take the moisture and the ash and the heat units and the price and reduce them to one figure, you get a splendid comparison of the same kind and grade of coal. You can take your screenings and compare them, take your nut coals and compare them: then pick out the best coal from the seam, run evaporative tests, reduce your cost down to the cost of making a thousand pounds of steam, sample your coal while this test coal is going in, then take the analysis that is made from the samples and use this for identification purposes in the future.

But this sampling and analysis must be in the hands of people who know how to do the work. There are great fluctuations in laboratories. There is no question about that at all. It seems too bad that that is the case, but you will find it; we have found it, but I can frankly say that today this kind of work is being standardized; it is becoming better in every way. The deficiency in sampling is being corrected, the laboratory methods are being standardized, recognized machines are being used, and there has been in the past ten years great strides in trying to standardize this method, trying to find a method whereby it would be both fair

to consumer and to the operator to buy their coal upon some kind of an equitable basis.

As Mr. Taylor has said, there are people in the coal business who try to get by. They think that they can put in a bid and get by some way—one way, when the coal is being bought upon the B. T. U. basis, is to try to fix the sample or fix the laboratory, or something of that kind. That thing, though, I think is way in the past, because everybody recognizes that check work can be done. You can take these samples and have somebody present when these same tests are being taken. I realize that is almost impossible in public institutions, and they are at the mercy of the people that take these samples. But it is my belief in these specifications that some one person should be mentioned who can do this work, and who can be relied upon to carry the work on in a fair and equitable manner. I am convinced that if this work is carried on right, as it should be, that it is one of the good ways, one of the best ways, to purchase coal, and arrive at a fair market value. A man that has a better coal can get a better price for this coal, simply because he can show the consumer of coal wherein his coal is better—it has less ash, it has more heat units, less sulphur. He can sell it for a better price than the operator who has a poorer coal. It seems to me that if this thing is conscientiously gone into that a great deal of good can be done through it to the purchaser and the buyer.

Mr. Postel: I will give you a brief outline of the way the state has gone about sampling the coal and some of the results we have got. I realize that everything depends upon the way the samples are taken. You can readily realize some of our difficulties when you realize that there are twenty-eight institutions in twenty-eight different cities, all of them getting this coal, and our control naturally is rather limited over the men scattered all over the state, but we have been able to accomplish this. In the first place, we had all the men in Chicago for a meeting of the chief engineers, and at that meeting the men were instructed how to take the coal samples and what to do with them after they had them. They were then given written instructions. At this meeting they were given the opportunity to ask questions and discuss the matter, then given written instructions which they took back with them. In addition to that, whenever we had occasion to doubt a sample, we followed it up from my office and tried to find out the occasion for any variation. We have at most of the institutions sample grinders, so that at least we eliminate the personal element there. By that I mean not only the personal element in quartering it properly, but furthermore it is a motor driven machine, and it is just as easy to put in a little more coal, and they are not stingy about taking a good big sample and grinding it down so that we get a fairer average than where a man has to grind it down by hand.

A question came up as to the kind of cans to use. We are using a screw top can which we seal with elastic tape. While I

don't believe it is absolutely moisture proof, we have had some very close checks between samples, analyzed when the coal was received, and those received a few weeks later when another test would come in. This is further made sure by the fact that we take two samples. As the cars come in there is a sample taken from every car. That is put away, ground down, put in a sealed can and labeled and put on the shelf. Then when not to exceed ten cars are received or not to exceed one week's time has elapsed —you see there are two limits there—never more than ten cars in one composite, never more than one week's waiting for the composite. These samples are then taken down and put into a general sample. Here again we require this precaution. The portion of each sample can that goes into this general composite is in exact proportion to the weight of the car from which the sample was taken. Suppose we have a 60,000-pound car and a 100,000-pound car. The 60,000-pound car will have only 6/10 as much weight going into the composite as the 100,000-pound car. A good car or a poor car affects the total composite only in the direct proportion which the weight of that car bears to the total weight of the coal in question.

At the larger institutions we usually run ten cars to a composite sample. Then after these ten cars each represented by a can—a certain weight out of this can—to get at this proportioning—is dumped into a receptacle and that is again put through the grinder and a five-pound sample filled, representing this composite. There are two sample cans filled; both of them are marked with the numbers of the cars that are represented in these samples. One can is put in a room and instructions are to take proper precautions as to temperature, etc. The other sample is sent to the university for analysis.

When a report is made there are four copies, one of which is immediately sent to the contractor. If he objects to the analysis he notifies us, and he then has the right to have the other sample, which is the other half of the sample, you might say, the other can which is held at the institution, sealed, sent to any laboratory that is mutually agreed upon between the contractor and ourselves. We then have a check analysis made. We have had a number of those made and the results have for the most part agreed very well with the original samples. In a few cases they have showed a discrepancy. I remember one case in particular where one sample of nut showed a very poor test, so poor that it was very evident something had gone wrong, and when the contractor called our attention to it we looked up the other samples of the same date and we found a sample of screenings that showed exceptionally well. They had become mixed in the laboratory; but that has happened only once, and we are sure that it won't happen again.

The question has come up as to how close—how nearly correct the sample can be taken. We have this further check on our men, besides, of course, our precaution. In addition to that, the thing that guides them in being careful is the fact that they know that

a lot of these mines are shipping to from two to half a dozen different institutions, and the reports from all the institutions come through our office, and they are tabulated, so that we will say a certain mine shipping to five different institutions, each one of those five men know that four other men are analyzing the same kind of coal, and he must get pretty nearly a fair average or else he won't check with the other four. The fact that they know that that check does exist, and is being followed up, I think, has a very good influence, and we have found it conducive to good results.

Screenings are more difficult to sample, probably, and I found a variation in check on screenings from the same mine, but two different institutions. One of them is the average of seven composite samples, which probably means 50 cars, and the other from eight composite samples, which probably means between 50 and 60 cars. In that case the B. T. U.'s, as received, were: Institution No. 1, 10,087; No. 2, 9,914. The variation is slightly more, perhaps one and a quarter per cent, or something like that, but for an average of that many samples it shows that those samples were taken with considerable care. Of course, if each sample showed that close, I would think there was something the matter, but they should average on the principle of averages. If, say fifteen samples at one institution checked seven at another institution as closely as that, the samples are being fairly well taken. I want to say, however, in my opinion I can readily see the objections to the method of taking samples. The contractor undoubtedly is at our mercy. I have done the very best I could to get the men to be fair about it, and to do the best they could in getting samples, but I can see objections to a contractor letting the other party take the samples. The best we can do to stop that is to let the men know that we are checking one institution against the other.

Furthermore, let the contractor go out with us, or alone, if he prefers, and take samples off the same car that the chief engineer has already taken samples, and check those in any laboratory, either the university or some recognized commercial laboratory.

Mr. Naylor: This appears to be a discussion of whether a public institution shall buy coal on a B. T. U. basis. There was a time thirty-five years ago when I first began to buy coal when there wasn't an honest coal dealer in the city of Chicago. The men that got on the street were not honest. I say that without any hesitation at all. But that day has gone by. I don't imagine from the remarks that have been made here tonight that anybody can expect the public institution to buy the coal on any but the B. T. U. basis. The necessity for that has gone by for the general buyer, I mean for the concern that I represent, or any other concern burning 200 tons a day can find a large number of coal dealers and operators and get their coal with absolute confidence, and get their coal without going through all this red tape.

Mr. Taylor: The method of calculating heat value contracts was developed in 1904 by Mr. Edwin H. Cheney and myself. Mr.

Postel copied the same, but he didn't copy it quite right. That contract was developed with the intention of fixing it so that the consumer only collected the damages for the actual damage done to him, and didn't collect any penalty. We made a series of boiler tests at the N. K. Fairbanks plant, where the contract price of coal was $1.65, and where the delivered value of coal ranged as low as $1.85 down to $1.52, and it showed that that contract was fair and equitable as far as the operation of the contract itself was concerned. The state contract, as I showed in my paper, is collecting over $50 a month for a variation of one per cent in the ash and one per cent in the moisture, which they couldn't sustain in court if the contractor went after them. That objection can be eliminated by using a form of contract which is absolutely equitable. The sample-taking proposition is the one with which we had all the trouble.

The proposition that the retail coal merchant is working on at the present time, I believe, is going to be a satisfactory method—that is, to grade the coal—grade it by the ash in it.

Mr. Naylor told the truth. He doesn't need to go back thirty-five years in the coal business to find that it had the lowest reputation of any business in the world. That is what brought the heat value contract into existence.

If the coal operator and distributor can have the coöperation of the buyer, and the buyer can understand the situation and will buy the coal that the coal operator has, and not ask him to try to deliver coal that he hasn't, I believe that the coal can be delivered in such a way that the buyer will be afforded all the protection that can possibly be given to him and thus prevent the fellow that is doing something crooked from getting the order, and finally driving him out of business. Then I think the coal business will be as ethical as the engineering business.

Mr. Postel: One point came up that I want to refer to, that is the reduction for ash. I meant to speak of that. In my opinion there is absolutely no question that a reduction for ash should exceed the mere cost of handling the ash. We all know, in fact, if you want to make an absolutely theoretically correct reduction for ash, you would start with a comparatively low reduction and increase very rapidly after you got up above 15 per cent ash. After you got past about 15 per cent the deduction for each per cent should go up quite rapidly.

Everyone that has purchased stokers knows that a stoker contractor will not merely take a contract to show a certain evaporation with a stoker under a certain kind of a boiler; he specifies the B. T. U. of the coal. In other words, if you give him real dirty coal he will not show the percentage of efficiency that he will with a cleaner coal, a coal with less ash, so that the manufacturer of stokers, as well as the operators of plants, realize that the percentage of ash is a distinct detriment, and if you are going to pay for coal on the basis of the good it does under the boiler, you must deduct for ash in excess of the cost of merely handling the ash.

Modern Tendencies in Roundhouse Design

By Exum M. Haas,
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Presented May 12, 1919.

THE increased sizes of locomotives, their high cost and large hauling capacity have brought about marked changes in modern roundhouse requirements. Economic conditions are also affecting design because the railroads must compete with other branches of industry. It is with these ideas in mind that I shall first discuss the broader questions of design and construction of engine terminals, and particularly roundhouses. You would undoubtedly be more interested in knowing where the money to build them is coming from. I will not attempt to tell you, but I believe it is safe to predict constructive railroad legislation within the year, and let us hope it will carry with it real railroad prosperity.

An engine terminal is a clearing house for motive power, hence anything done to obviate delays tends to increase the traffic carrying capacity of the road, without increasing the fixed charges.

The tremendous increase in traffic, operating charges, and hauling capacity of locomotives and their cost has proportionately increased the demand for full utilization of a locomotive's earning power. Mere minutes saved on each locomotive handled, when multiplied by the total number of locomotives of a given road, and reduced to money, will finance unbelievable improvements.

For instance, the total operating revenue, as shown by the United States Railroad Administration's reports for 1918, was $4,913,000,000, or an increase of over 200 percent over that for 1900. On the other hand the number of locomotives in 1918 was 64,000, representing an increase over the same period of only about 70 per cent. However, this is a very excellent showing and indicates clearly the increased efficiency attained. On the basis of the 1918 revenue, the average annual earning capacity of each locomotive was about $77,000. Based on a 320 working day year and a 20-hour day, the earning capacity per locomotive per hour is $12 or $3 every fifteen minutes.

For a terminal handling 100 engines per day fifteen minutes saved in the time consumed in clearing each engine would amount to $300 per day, or $96,000 for a 320-day year. This saving could eventually be realized by converting it into a reduction in the total number of locomotives required to move the traffic of a given road.

Another angle of the value of the time saved may be expressed in terms of fixed charges. The total value of all railroads in the United States is around $20,000,000,000, and there are 64,000 locomotives. This reduced to plant value per locomotive equals $300,000.

The average annual rate of interest and depreciation applied to the entire railroad property is about 10 per cent or $30,000 for

the $300,000 worth of value. Thirty thousand dollars per year represents about $1.20 for each fifteen minutes. Reversing the calculation, and applying it to a 100-engine terminal, fifteen minutes saved on each engine per day for 90 days per year would equal about $10,800. This time saved represents reserve capacity which can be used in emergencies. If capitalized it would finance terminal improvements or purchase new equipment.

I have dwelt on this phase of the engine terminal problem to indicate what a road could afford to pay for the most efficient facilities. As a matter of fact, a 100-engine terminal can be built at present day prices and fully equipped for about $660,000, divided as follows:

APPROXIMATE ESTIMATE OF COST OF AN ENGINE TERMINAL.

Handling About 100 Engines Per Day.

Grading, Drainage and Track	$ 70,000
Two Inspection Pitts and Service Bldg	16,000
Coaling and Sand Station, Water Supply, etc	74,000
Two Water Type Ashpits and Gantry Crane	36,000
Oil House and Equipment	10,000
100 Ft. Turntable Pit and Table	20,000
24 Stall Roundhouse, Type B	220,000
Machine Shop, Power House and Annex	64,000
Boiler Washing, 10 Ton Crane, Electric Hoist, Shop and Power House Equipment	120,000
Miscellaneous	30,000
Total	$660,000

This would result in annual fixed charges of about $69,300, at 10 per cent for interest and depreciation, or at about $2 per engine per day. For a terminal of this size, a 20 to 25 stall roundhouse would be required. Assuming 24 stalls, the house would cost about $220,000, or about one-third of the terminal cost. This amount would provide a roundhouse, equipped with all the modern labor saving facilities, and it could be so constructed as to reduce depreciation to a minimum. For instance, a reinforced concrete structure would carry a rate of about 2½ per cent for depreciation, whereas a brick wall, wooden frame and roof structure would carry at least a rate of 5 per cent for depreciation.

Some roundhouses are quite important running repair shops; hence anything incorporated in the design that will reduce the time to clear a locomotive should be adopted. Of course, there is an economical limit to the amount that can be spent, but that need not worry most of us, because there is so much room for improvement at most terminals that we would find it difficult to reach the limit of cost. For instance, engine terminal costs varied in 1918 from $25,000 a stall to $50,000 a stall of house capacity. The roundhouse proper has varied in cost from $6,000 per stall, with lighting, heating and plumbing, to $22,000 per stall. Both of these figures are high for the types of construction used, because of the abnormal labor and material market conditions prevailing in 1918, but the

cost relation would hold even in normal times. On the other hand, from what I know of the labor saving facilities provided in the high priced terminal and the permanence of its construction, I believe the mechanical department will have no difficulty in justifying its cost.

VALUE OF REMOVING FIRE HAZARD

It is also interesting to note the other data which indicates very clearly the added importance of protecting locomotive investment due to both increased cost and hauling capacity. While the weight of locomotives has increased about 100 per cent the cost has advanced from $148 to $260 per ton. This also emphasizes the need for better facilities for the protection of the motive power. A locomotive is not a fire risk in itself, but when it is placed in a wooden roof roundhouse it certainly becomes one.

Frankly, I am a firm believer in reinforced concrete roundhouse construction. In my efforts to sell this idea to others, the question of removing fire risk has frequently come up in conversation and just as frequently I have been told fires never occur in engine houses. I will not attempt to disprove this claim, but I will call your attention to a particular instance where this claim was made and two houses with a total of about thirty stalls burned within a year after I was advised that the road had never had a roundhouse fire. In each instance, the house was a brick wall and wood frame, wood roof structure, and at the time of the fire each housed a number of locomotives. These fires put fourteen or fifteen locomotives out of service and all had to be dead headed, some over one hundred miles, to the general repair shops. A fire in a roundhouse presents a greater hazard than in any other type of shop building; first, because it houses the most valuable part of the road's rolling stock, and second, because the roundhouse crew is helpless to remove most of the engines when a fire does occur.

I might mention that we had occasion to bid on a roundhouse structure in wood and concrete. We designed the concrete structure, following the same roof contour, the same depth of stall and the same vertical clearances as the wood and brick house. We were given prices for gravel, sand, cement, and I believe brick that were obtainable on the road. About six thousand dollars per stall was the bid price for the wooden structure and the bid on the concrete house was only five hundred dollars a stall more. That was at a time when lumber prices were high—last summer. I believe that with present lumber prices and a lower price perhaps in cement, a better efficiency from labor—our labor was off about fifty per cent last summer—we would be able to make a little better showing than that. But it gives you an indication of how closely the two can be brought together if an economical design is used.

EFFECT OF LABOR AND IMMIGRATION

Another of the broader questions affecting roundhouse design at present are immigration and labor conditions. The former affects the quantity and class of help available, and the latter deals

with working conditions and wages. Failure to consider both of these is overlooking vitally important factors. Existing industrial conditions have permitted the intelligent labor to obtain employment at higher wages and with more satisfactory working conditions than are commonly found in and about a roundhouse. The roundhouse design must meet this form of competition or the quality of labor will fall below its present standard, and roundhouse labor is none too intelligent now. This, together with the possibility of a shortage in unskilled labor, presents a serious prospect. Moreover, I believe I am safe in saying that we cannot look to immigration to fill up the ranks of our lower strata of labor for some time to come. The average labor available will not seek employment in a dark smoky roundhouse when better surroundings can be had elsewhere at the same or even slightly lower pay.

Conditions in the average roundhouse built 20 years ago were not conducive to efficiency or economy. Poor day and night illumination and a lack of proper handling and machine tool equipment not only reduces the capacity of the roundhouse for clearing locomotives, but results in serious delays. On the other hand, the shortage of desirable help and the correspondingly higher prices that must be paid to obtain good men, makes it important that all the facilities necessary and consistent with economy be provided to increase the production per man. The increased use of bridge and jib cranes in roundhouses is evidence of an appreciation of this fact. The substitution of the electric hoist for the truck and driver drop pits is another example. Improved daylighting in the working areas, and better heating and ventilation are also examples of the tendency to improve roundhouse conditions. Paved floors and walks, attention to good drainage, add to engine terminal efficiency and do not materially increase the fixed charges.

CONSERVATION OF RESOURCES

It is not only a duty, but has become a necessity for us to conserve our natural resources. I need not tell you about the lumber situation nor the difficulty experienced in obtaining the quality of material we should have for roundhouse construction, especially East of the Mississippi River. Lumber prices, I am told, are as low now as we may expect. This conclusion is based on the rapidly failing supply of timber close at hand and the long haul from our future sources of supply. A timber frame and roof roundhouse, with brick walls is the cheapest to build, but is it always the best? Inasmuch as timber structures normally carry about a 5 per cent rate of depreciation and concrete 2½ per cent, it appears that one could afford to spend 30 per cent more for concrete. This is unnecessary, as a 15 per cent to 20 per cent increase in cost is about the way to figure today, without taking into account the sand, stone and cement prices usually obtainable on most roads.

A high rate of depreciation also means more maintenance and its interference with roundhouse routine. Looking at it in another way, an effort should be made to reduce depreciation on as much of

the physical property as possible to offset the high rates applicable to rolling stock, rails, etc., that are subject to wear under traffic.

MODERN TYPES OF CONSTRUCTION

Modern roundhouses divide themselves into three classes—the brick wall, wood frame and roof; reinforced concrete frame and roof; and a combination of steel frame and reinforced concrete structure. In one or two instances, concrete frames with wooden roofs have been built to reduce first cost, and in others reinforced concrete unit construction was adopted. Under certain conditions and for certain purposes, particularly where there are a small number of forms required and great duplication, the unit construction may be economical. It will always have its inherent structural weakness, however, and require a larger handling charge than poured concrete. On the other hand, all parts may be precast under ideal conditions and perfect concrete obtained. Theoretically, we ought to be able to stress up the steel and concrete, but this does not work out because the units must stand handling. In one instance with which I am familiar, six or eight roundhouses of ten to twenty stalls each were located at some distance from a central precasting plant. I understand that the roads engineers have figured that the transportation of precast units required 40 per cent more car miles than if the poured type of house had been adopted. This was due to the fact that much of the construction material could have been purchased near each terminal site. In addition, loading, unloading and erecting derricks of at least ten tons capacity were required at the precasting plant and at each site to handle the heavy columns.

The brick wall, wooden frame and roof construction has been most generally used because of its cheapness. Relatively, long life in structures of this kind require first quality timber, and this is not only difficult to obtain but it is high in price. Fire hazard and a high rate of depreciation are the two most serious objections to timber construction.

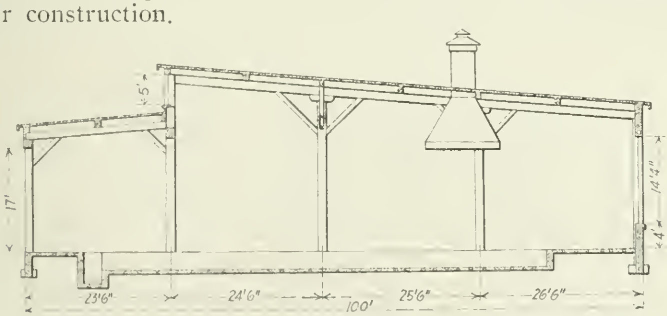

Fig. 1

TYPICAL ROUNDHOUSE SECTIONS

The section shown in Fig 1 is the one most generally used. Where the roundhouse is located at an unimportant terminal, and the engines are comparatively small, this type of house is all that is

warranted. The present tendency, however, is to increase the height to improve daylighting and ventilation. Houses of this type should be built of slow burning construction throughout—nothing less than two inch sheathing and preferably three inches on 6 in. x 12 in. rafters—and all S. 4 S. and heavily coated with a fire resisting paint.

On many roads the frequent post spacing has been found objectionable. This was the case with the New York Central Lines, and a 64-foot truss has been substituted in the working area for the columns and beams. These trusses (Fig. 2) are of heavy timber construction, but now they are built up of bolted planks. The reason for this change was to cheapen the construction without reducing the quality of the lumber. You will also note that this New York Central house has a one bay portal way, with a leanto at the back of the house. The leanto in the rear not only provides a working aisle, but also permits the locomotives to be

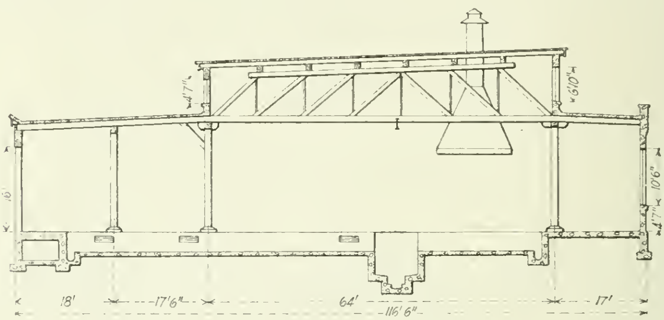

Fig. 2

shifted over the driver and truck drop pits. There is some difference of opinion regarding the leanto, but it is undoubtedly a cheaper construction than if the trusses had been carried the full width of the house.

In the case of the Big Four Railroad, another New York Central Line, a pitched truss is installed at the rear of the house, and the back wall is sufficiently high to provide good daylighting even where the stall length is 100 feet. One advantage of the pitched truss is that it permits the smoke to flow more freely to the single row of ventilators along the ridge of the roof.

In but comparatively few instances have the reinforced concrete houses, which are now being quite generally used, followed the same section as the wooden frame roundhouses. Generally speaking, however, they have been of the monitor type construction, varying principally in the number and spacing of the columns. For instance, the Philadelphia & Reading roundhouse (Fig. 3) is a three-bay construction, two low bays on each side of a monitor section. The interior columns are all structural steel encased in concrete. The reason for adopting this type of column was to permit the installation of a jib crane. The roof is a combination floor

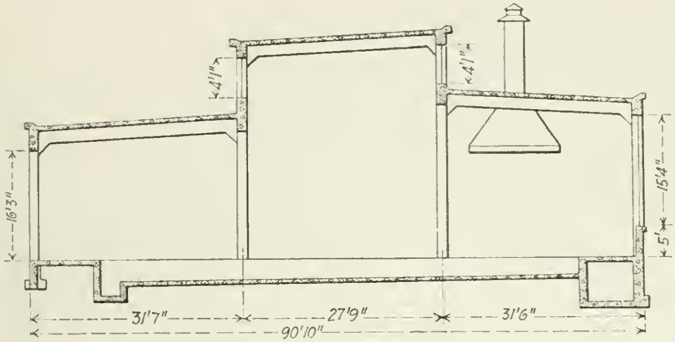

Fig. 3

tile T-beam construction to form an insulating medium against temperature changes and condensation. All sashes are of steel with pivoted ventilating sections. As an aid in ventilation, five permanent slot openings were provided at the ceiling line between each set of columns in both sides of the monitor and through the back wall. In addition, of course, there is the smoke jack and the opening around it.

I believe the first instances where a bridge crane was installed in a round house was that in one built by the Baldwin Locomotive Company at Philadelphia. This was built for repairing locomotives and is equipped with two cranes, the larger of which is 50 tons capacity. Among the first of the bridge crane types of houses built by a railroad was that of the Pennsylvania Lines East at Altoona, Pa. It was constructed in 1902 and consists of 52 stalls, handling an average of between 250 and 350 locomotives daily. The head room in the crane section is about 30 feet and the crane capacity is 12½ tons. It is interesting to note that an analysis of roundhouse crane requirements on the Pennsylvania Lines East made recently, developed the fact that the maximum load that a crane would be

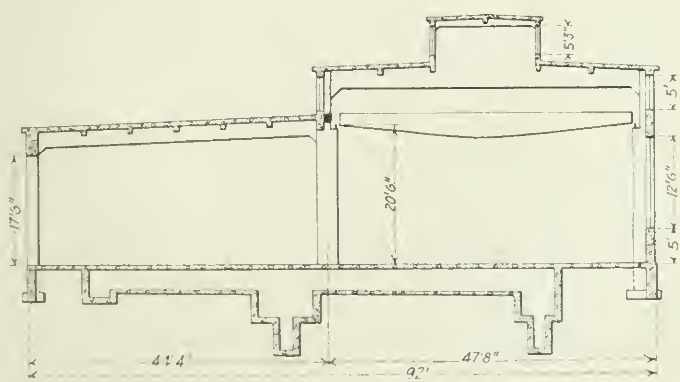

Fig. 4

required to handle was about 8½ tons. This meant that a ten ton crane would be adequate for all purposes.

The height of the crane rail above the track, I believe, should be about 26 feet. The usual practice has been to put the crane rails too low to permit of easy handling of repair parts. Twenty-six feet will permit the operator to pick up a cab and carry it bodily to a locomotive over one in an adjoining or adjacent stall without interference.

As a novel section, I would call your attention to the one being used by the Santa Fe. (Fig. 4). Another house along similar lines and one which has been described quite frequently in technical journals, and railroad engineers' hand-books is that of the Western

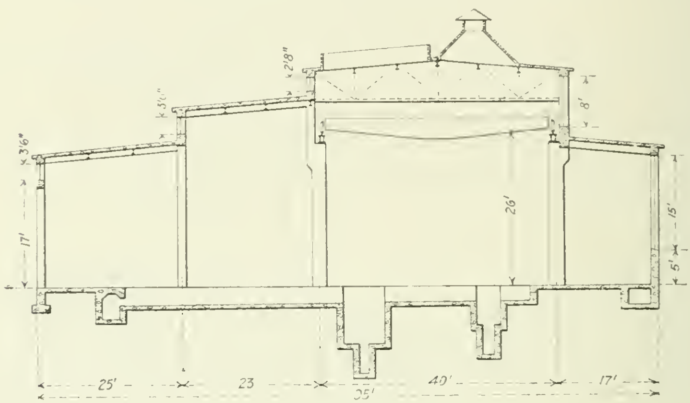

Fig. 5

Maryland at Hagerstown, Md. (Fig. 5). This house is a steel frame construction, encased in concrete. Woven wire mesh was wrapped about the steel, and the concrete put in place by the Gunite system. The roof slab is 3-in. concrete with Hyrib reinforcing. The roof is of double monitor construction, permitting daylight to enter at three points in addition to the back wall. The crane in the high section spans the working area and has demonstrated its economy. It is said that the crane installation paid for itself in this house in one year.

In connection with steel frame houses, built-up columns, girders of heavy section are being used as the frame in the new houses recently built by the Pittsburg & Lake Erie Railroad. This company believes that proper attention to painting will give unusually long life to these steel frames.

I am also told, in connection with this house that they have adopted a gypsum roof.

I was recently in a roundhouse used by the Kelly Island Limestone Company, Kelly Island, Ohio, where very frail looking old style rod and pin wrought iron trusses have been in service, for

over twenty years. Their present condition indicates practically that much more life could be expected from them. This long life was apparently not due to the attention given to painting these trusses during the period of their service.

BEST REINFORCED CONCRETE SECTION

In connection with my company's efforts to help the railroads arrive at a section of roudhouse for its purpose, we spent some time in investigating existing types. We found that there was really a need for two house sections—one for the important terminal where considerable running repair work was handled, and another for a terminal of lesser importance. The stall length to be adopted was brought out in our Mr. Lemmerich's article in the Railway Age of March 14. As tentative lengths he recommended 90 ft., 100 ft., 110 ft., and 120 ft., based on the following conditions:

(a) For short line roads, branch lines where no heavy power is required, and where locomotives not much over 70 ft. in length are used the stall length recommended is 90 ft.

(b) At unimportant terminals for smaller roads with comparatively light power and handling locomotives not over 80 ft. in length, the stall length recommended is 100 ft.

(c) For more important terminals, handling Mikado, 2-10-2, and a few 2-6-6-2 Mallet locomotives, the stall length recommended is 110 ft.

(d) For engine terminals, handling few 2-8-8-2 Mallets, besides the ones mentioned under paragraph (c), a combination of a 110-ft. house, with a few stalls of 120 ft. for the Mallets, is recommended. The section of the house should be such that extensions can be made readily.

(e) For important engine terminals, where a crane installation is desired for locomotives under 85 ft. in length, a 110-ft. stall length is recommended. For locomotives over 85 ft. in length or where more working space is found desirable, a 120-ft. house is suggested.

(f) At terminals where a few of the largest 2-10-10-2 type Mallets are handled, a similar combination to that outlined under (d) is suggested.

The depth of the Mallet section in this case, however, should be 125 ft. for Mallets up to 105 ft. For Mallets over that length the stalls should be lengthened correspondingly.

Type "A," (Fig. 6) house is recommended where repairs are light and type "B" (Fig. 7) house where running repairs are quite heavy. The type "A" house, is reinforced concrete frame with a column spacing that would result in economical concrete beam construction. The roof slab is flat on the under side, and is formed with 8″ x 24″ floor tile, and 4″ concrete T-beams. This provides an insulated roof and one which is just as cheap to construct as the plain slab. The concrete T-beams support the roof load between the longitudinal beams which follow the center line of the

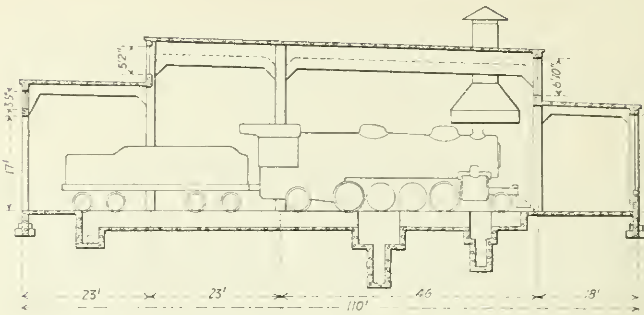

Fig. 6

stall. Our object was to obviate smoke pockets in the roof which would be formed if cross beams had been provided. The location of the monitor windows is such that it will throw daylight into the working area,—5′2″ of sash provided on the front of the house and about 7′ of sash on the back of the monitor. In addition, the sash area in the leanto at the back of the house is 13′7″ high. Provision has been made for omitting one set of columns in the drop pit section. This was to provide a clear floor area between the pits for removing wheels from the drop pits to the back of the house. Permanent openings 4″ x 18″ in section at the front and rear of the monitor and just below the roof slab will take off the gases which collect at those points. The arrangement of the sash and the provision of a brick curtain wall at the rear of the house simplifies repair work in case a locomotive runs through the house.

So far as we can learn, the life of steel sash in a roundhouse is somewhat longer than that for wooden sash in the same location, and it is just about as cheap. If it is kept well painted, steel

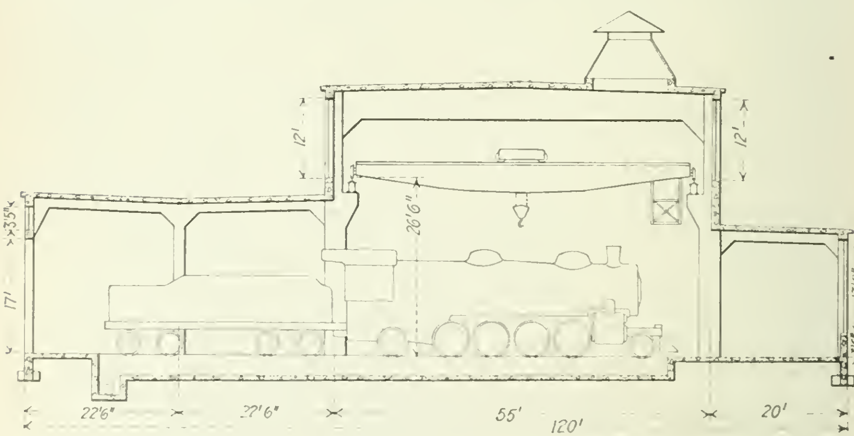

Fig. 7

sash has the additional advantage of not swelling under excessive moisture, and the ventilators are just as readily operated in the winter months as in the summer.

In the type "B" section, the crane span is approximately 50', which, with a slight shifting of the locomotive, permits it to reach any of the heavy repair parts which have to be handled. The height of the crane rail is 26'6" above the floor line, which is sufficient to permit of the crane removing the cab without striking other parts of the locomotive. This height also greatly facilitates all crane movements. The leanto on the rear of the house, as mentioned before, not only provides space for the benches and the movement of repair parts from the roundhouse to the back shop, but gives that flexibility which is required at the drop pits. In a house of this kind, the objection may be raised to the fact that

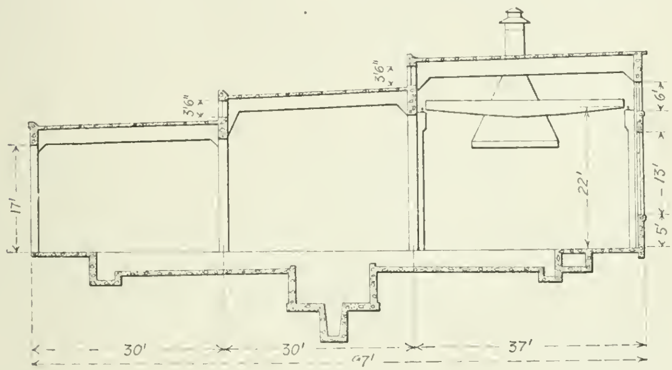

Fig. 8.

smoke and gases flow freely from the locomotive and fill the entire monitor section. In other words, the crane installation does permit the installation of the usual smoke jack. It has been found in houses of this section that the high monitor and the installation of a large ventilator or jack in the roof over each stall, does not result in an objectionable accumulation of gases and smoke. In the winter time, and even in the summer, the fan in the hot blast heating system can be kept running to force out the gases. The outlets to the heating system are through grates in the sides of the pit walls.

I also want to call attention to the growing tendency to substitute the electric hoist for the truck and driver drop pit. In addition to reducing liability of accidents it removes wheels quickly and cheaply. While this hoist is sometimes installed in the roundhouse, its proper location is in the back shop. In any case, the back shop should be connected with the roundhouse by a passageway, lined up with the turntable, so that the dead locomotive can be pushed through the house into the back shop. With the electric hoist in the shop section, the removal of wheels is under proper

supervision, and the handling of repair parts to and from the various machine tools is but a short distance. Placing the hoist in the back shop, also releases a stall for regular roundhouse service. Serious objection to the drop pit has developed in recent years, owing to the extremely heavy locomotives and to the declining quality of roundhouse help. While accidents, due to jacking up the locomotives for the removal of wheels, do not occur frequently, there is always the liability and it has greatly increased with the failure to obtain intelligent labor.

ROOF DRAINAGE

A 4 or 5-ply built-up roof is very necessary to good roundhouse construction. There has been a recent tendency to substitute the prepared flashing for the copper or galvanized flashing which has been so generally used. Experience seems to demonstrate that the prepared flashing is more satisfactory than the galvanized, and about as good and much cheaper than the copper. Interior down spouts at the first column inside the door opening remove all roof drainage from the front of the house where it is very objectionable.

With the curved roof in a roundhouse the valley construction does not collect drifting snow as it does in a rectangular building. The wind has a sweep at the house from practically every direction, and those who have had long experience in roundhouse maintenance advise that they have never seen a great accumulation of snow on the roof. By pitching the monitor section to the rear of the house, as well as the leanto to the back, practically all the roof drainage is carried to a point where it does not interfere with the operation of the house.

Two types of roundhouse doors are quite generally used—the two leaf steel frame, wooden swinging door, and a rolling wood slat door. The former is the most popular because repairs are more readily made.

The question is frequently raised whether or not it is desirable to provide sash in the door or in a transom over the door. Sash in the door permits lowering the roof level, but to some it is objectionable because the rough usage results in frequently broken glass. Daylight at the front of the house is not so essential, and all that is really needed may be had through small transom sash. On the other hand it has been found that most of the blows which would break the glass in the door would break a wooden panel, and the glass is more readily replaced than the wood. For that reason, the glass area in the doors is made quite liberal in the houses built by a number of roads. We built seven terminals in the last year consisting of 115 stalls and glass in the doors was specified for all except 13 stalls.

HEATING SYSTEM

Another tendency in roundhouse design and construction which has come into more general use in the past few years is the substitution of the hot blast heating system for the pipe coils or other

forms of direct radiation. A hot blast heating system installation costs very little more than a direct system, and it has the additional advantage of providing forced ventilation in the house, which is often very necessary. At first the selection of too low fan and radiation capacity resulted in the indirect system being unsatisfactory. This has been corrected, and the fan may be speeded up in extremely cold weather to raise the temperature for thawing out frozen locomotives.

In connection with the heating plant installed in the Western Maryland house at Hagerstown, Md., the following data may be of interest. An average temperature of 65 degrees is maintained at zero outside by a 137 in. fan operating at 157 R. P. M. The cubical contents of this house is 1,640,500 and the fan provides for six air changes per hour. In another house equipped with a smoke exhaust system, three changes per hour was deemed satisfactory, inasmuch as the forced ventilation feature was not so necessary.

A recent development in round house equipment has taken the form of a smoke exhaust system. While possibly these installations were first considered as a means of abating the smoke nuisance, their economy has resulted in their being installed in quite a number of houses, where smoke is not objectionable. I understand that at first these smoke exhaust systems included the installation of an electrical precipitator. All the smoke exhausted from the roundhouse is passed between two high tension terminals, where carbon particles were charged and dropped to a collector. The gases pass beyond this precipitator and are discharged into the air through a stack. I understand that the precipitator was not found to be economical and is no longer being used as a part of the smoke exhaust system. In the installations with which I am acquainted, the smoke is taken off through twin jacks into a smoke duct which connects with a stack just beyond the exhaust fan.

One of the questions raised in connection with the smoke exhaust system, was where to put the duct. At first the idea was that possibly the duct could be a re-enforced structure carried on columns under the roof. To get a duct structure that would stand up under the acid and gas action, required such a heavy one that it was found impracticable to carry it overhead, so the next move was to put it under the floor. There was a question as to whether it ought to go under the pits or whether it ought to go at the back of the house beside the heat duct, so we finally decided to go so far as to put it outside of the house altogether, which is a pretty good place. In one instance I know sheet metal duct was located on the roof of the house.

DISCUSSION.

Mr. Walsh: What particular effect has the sulphuric acid gases on the cranes in the type "B" house, where they have to travel back and forth through the path of it?

Mr. Haas: The crane does not have occasion to travel back and

forth in the gas very frequently. The P. & L. E. have built not only one, but several houses with structural steel frames and it is purely a question of paint maintenance to resist corrosion.

Mr. Walsh: What is the age of the oldest house of that type?

Mr. Haas: I mentioned one here that was twenty years old, built with wrought iron rod and pin trusses. I will venture to say that house will stand twenty years more. At the time I saw it the trusses looked as though they were of sufficient size to more than support the roof when originally put in and seemed to be in a good state of preservation. The company has no intention of building a new house at this time.

Question: How do you explain the fact that the ordinary house that has smoke ducts provided, the conduit and other metal, although protected, only has a life of six or seven years? Those are the conditions existing in several places.

Mr. Haas: That is hardly a question of the kind of material you are going to use. In every house shown on the slides, the electric conduit is encased in the concrete.

Stanley McCassey, A. W. S. E.: I want to ask what is the result of gases on concrete? Has any concrete house been in use long enough to get a test of that?

Mr. Haas: That question has been brought up frequently. The best answer that I can get is that if there is any deterioration, it is not very much. If the gases and the acid action do attack the concrete, it is unnoticeable.

Question: How about the condensation of water on the concrete roof?

Mr. Haas: With 66 per cent exposed floor tile or cellular tile to 33 1/3 per cent for exposed concrete beam in the roof slab in a house on the Delaware & Hudson, during the winter of 1917-18, there was no condensation. I think that the floor-tile T-beam construction is an absolute insulator against it. But we believe a step further is certain and use a 24-inch tile, instead of an 18-inch tile. It is interesting to note that one of the most conservative roads, one of the roads that is always very careful about its choice of construction, is going so far as to build a plain slab roof in all its new roundhouses.

Walter S. Lacher, A. W. S. E.: The speaker referred particularly to the use of smoke exhaust systems, and I gained the impression that a number of railroads had taken rather favorably to the smoke exhaust system as a matter of economy. This is decidedly divergent from my own understanding that smoke exhaust systems had been installed only in such places where the railroad could not get along without them, where the company had been forced to do so by the "smoke nuisance" department, if you can call it that, of the city to reduce the smoke nuisance of the roundhouse. I understand that a smoke exhaust system is expensive, not only as to installation and maintenance but as to the power consumption in

the operation. Those gases, especially where they are subject to low temperature and where there will be a condensation within the duct, are very corrosive, and particularly the fan itself is subject to very serious deterioration. Therefore, I would like to ask Mr. Haas if he knows of any case where the railroad company has put in an exhaust system of its own free will. My understanding is that modern tendency is to improve the ventilation of the house itself, so that if any smoke from the engine stack fails to get into the smoke jack it will be carried away by a properly designed monitor system. In the early days the smoke jack designed consisted essentially of a cylinder in close proximity to the smoke stack and this design has been almost entirely eliminated in favor of a closed jack extending longitudinally in the house, so that the engine does not need to be spotted exactly. That is an improvement to the smoke exhaust system, in that, with the smoke exhaust, the smoke jack must come down close to the stack; otherwise you need an excessive fan capacity, because you will be pumping air as much as smoke.

Mr. Haas: We are building a roundhouse in a city of 1,200 people. The roundhouse is three quarters of a mile from the center of this city and we are providing a smoke exhaust system. I understand there are economies in connection with an exhaust system of this kind that more than offset the additional cost to the roundhouse. It is my understanding that in normal times the smoke exhaust system would run probably fifteen hundred to two thousand dollars per install. Take the matter of heating system. In a house with an ordinary smoke jack in the roof we have found that six changes of air are necessary. Experience has shown that three changes of air are all that is necessary with the smoke exhaust system. The engine gases do not have to be removed; neither does the outside air need to be heated.

The other question was one of the flexibility of the locomotive position in relation to the jack, and the smoke exhaust system. Some very neat jacks have been designed for that purpose. The upright portion of the duct, or jack, permits not only lateral but vertical movement of the locomotive. The jack proper is actually dropped down into the top of the locomotive stack so there is no loss of suction at that point. The exhaust system is in direct connection with the smoke stack proper. Flexibility is secured by the design of the jack and I presume it will give a lee way of five or six feet.

In connection with the jack installation, I recently saw a novel one in a house that the Cumberland Valley built at Chambersburg, Pa. It was found worth while to use in two jacks, making a twenty-four foot hood, so locomotives of any length may be handled. I believe the double jack system is also in use on the Pittsburgh & Lake Erie, which road was among the first, I believe, to install it.

Chairman: One of the features was the turntable. The length

was spoken of but not the type of turntable. The C. B. & Q. Railroad have been using a through truss type turntable, 100 feet long, which we believe to be more economical, not only in the weight of steel used but in the amount of excavation in the pit. It is a much shallower turntable and is very fine in places where the water is high. With a 100-foot deck turntable you would probably have ten to twelve feet. The use of through turntables for tables of this length is a point that should be considered.

Mr. Haas: What is the relative cost of the deck and the through table?

Mr. Haggander: I can't give the relative cost but I know there is a difference of possibly fifteen tons of steel in a table, and besides, considerable excavation.

Mr. Haas: That is, there is fifteen tons less in the through turntable than in the deck turntable?

Mr. Haggander: Yes, and besides that there is the difference of excavation and the ease of drainage of the pit. Drainage is one thing that is quite complicated in the deep pit. I notice there are very few of those using this new turntable and I can't understand the reason why they don't do it, because it seems to me such an economical proposition.

Mr. Haas: Natural drainage is such an important factor in the location of an engine terminal that frequently it is worth while to move the terminal to get good drainage. There are the ash pits, the inspection pits, and the pit under the track hopper at the coaling station. There are so many places that must be drained which are so much lower than the turntable pit that in a good many cases it is necessary to move the terminal to where natural drainage is good.

Mr. Haggander: I was speaking of the economy of the table itself.

C. F. W. Felt, M. W. S. E.: The Santa Fe have been building re-enforced concrete houses for a little over ten years. We have used various modifications of designs similar to that shown, and one of the features that may be of interest is this,—that we have used the concrete slab construction entirely, but all of these houses have been out west, the interesting feature being that we have not been troubled from the condensation. And in connection with the concrete houses or the concrete construction I will say we have had several that were built of the so-called "unit type." I think you spoke of some where they apparently cast the various parts and transported them some distance. In our case these houses were cast on the job. Therefore, that feature of it was not involved.

Mr. Haas: How many forms were required per stall?

Mr. Felt: There were 34 forms required to the stall in the houses I had in mind. These houses of that construction were built in competition with plans for the houses cast in place, on a lump basis. We as yet have not used any of the tile and concrete roof slabs, although it looks like a very good construction.

I will say in connection with turntables that we used the through girder type, which reduces the depth somewhat, under the deck girder.

Question: I would like to ask the speaker if he has figured any on the possibility of using a concrete stack for a forced draft system instead of mechanical draft? Inasmuch as it costs two thousand dollars a stall to put in mechanical forced draft systems, wouldn't it be more economical and do away with the maintenance and repair of mechanical systems to locate a stack at the center of the circle of the roundhouse, and then pipe all the smoke jacks into it, using natural draft?

Mr. Haas: I might say that in all exhaust systems in roundhouses that I know of (which is not very many) there is a 150-foot stack. No doubt a certain amount of natural draft is figured on to serve them, although there is an exhaust fan in the system.

Mr. Haggander: The speaker mentioned the fireproofing of the interior of the wooden roundhouses by painting with fire resisting paint.

Mr. Haas: That is merely "whitewash"; or "factory white." Another provision of this nature is to use all dressed timber as it is fire resisting.

Mr. Holmes: I would like to ask Mr. Haas if he knows of any cases where the smoke ducts or the exhaust passes have been outside the engine house? I understand that in some cases this is being done.

Mr. Haas: I know of one case where a smoke exhaust system was considered for an old house. The heat duct was between the ends of the pits and the back of the house and the smoke duct was to be placed just outside the back wall of the house. It would be necessary to re-enforce a duct in this position so as to provide for the time when a locomotive may go through the back of the house. I know of another instance where a steel duct was placed on the roof and carried quite a distance to a smoke stack.

Lighting in Wartime

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Presented November 25, 1918.

THE title of this paper may suggest lighting in its various military forms. It is indeed going to be an interesting recital when those who have had the honor of administering lighting in military service tell us, as they probably will, about the developments in searchlights, in star shells, in trench candles, and the developments of marine and land camouflage, etc. The record will show that lighting and iluminating engineers have indeed played an important part. But these same agencies have contributed largely to the war ability of the nation in other less conspicuous but very important ways. It is the purpose at this time to describe and comment upon this civilian service which has been rendered through artificial lighting.

This subject is approached very largely from the point of view of the committee on war service of the Illuminating Engineering Society. This is one of the numerous organizations which sought to be of service to the Government in the emergency. There were so many of these organizations that one was reminded at times of the case of the fleas.

> Great fleas have little fleas
> Upon their backs to bite 'em;
> And little fleas have lesser fleas
> And so on infinitum.

One of these little flea committees was the committee on war service of the Illuminating Engineering Society. When diplomatic relations were broken off with Germany in February, 1917, the Illuminating Engineering Society within a few days filed telegrams with the Secretary of War, the Secretary of the Navy and the Naval Consulting Board, offering the services of the society's members. Beyond a perfunctory acknowledgment, nothing resulted. At the time of our recognition of the state of war, further attempts were made to be of service and these for a time proved abortive. In the latter part of the summer of 1917, however, the society received its first call for service and this committee was immediately launched and it has been quite active ever since.

This committee sought not to work alone or in conflict with any existing agencies, but to affiliate itself as far as possible with activities which were under way or which were later organized. In its work it has co-operated with the national committee on Gas and Electric Service, which represents the electric and gas lighting companies of the country; with the divisional lighting committee of the committee on Welfare, Council of National Defense under Mr. Gompers. The society is represented upon the National Re-

search Council and upon the war committee of technical societies, and through this latter committee was in touch with the Naval Consulting Board and later with the inventions section of the general staff of the army. Both these affiliations afforded the committee valuable connections.

Some of the many civilian committees have served to advantage; others perhaps not to advantage. Our committee, I think, has served to advantage, as is attested by numerous letters of appreciation which it has received from the Navy Department, the advisory commission of the Council of National Defense, the Fuel Administration War Department.

In what I shall say about civilian lighting in time of war both electric and gas lighting are referred to, but there will be little direct reference to gas lighting. Gas lighting is a very special problem. In the first place it is not utilized so largely for display as electric lighting is, and therefore did not attract so much attention from the conservation standpoint. In the second place, the necessary for carbonizing a certain amount of coal in the larger plants in order to provide explosives was such as to make it unwise to curtail the use of coal in that industry. On these accounts special reference will be made principally to electric lighting.

Civilian lighting in time of war is valuable and can be made of service to the nation principally under four heads:

First. As a means of promoting production.

Second. As a means of providing protection for important properties.

Third. As a means of promoting safety.

Fourth. As a field in which conservation can be accomplished.

PRODUCTION.

In the matter of production, unfortunately the general idea is only that a little light is better than no light and possibly that plenty of light is better than a little light. Beyond that the layman does not go very far in lighting for the industries. The illuminating engineer knows that industrial lighting ought to be right in intensity, in direction and in degree of diffusion. W. A. Durgin and his associates on the staff of the Commonwealth Edison Company of Chicago have perhaps done more than has been done in any other city to demonstrate in a practical way the real economic value of good industrial lighting. In a recent investigation which was reported by Mr. Durgin at the convention of the Illuminating Engineering Society in New York early in October, 1918, it was developed after a series of trials in a Chicago machine shop that with lighting of triple the *intensity* which ordinarily might be deemed to be satisfactory, production rates ranged from eight to twenty-seven per cent in excess of those previously attained. In both cases I understand the lighting equipment was reasonably good, the only difference being the amount of light employed.

In further trials where antiquated, ineffectual equipments were replaced by modern equipments providing high intensity lighting,

sometimes as much as twenty-five times that formerly used, production rates were increased by from thirty to one hundred per cent in various plants. These figures may sound rather startling to the uninformed, but they are not in the least startling to illuminating engineers who recognized the fundamental fact, but have heretofore lacked authoritative data in demonstration of the points they thoroughly believed in.

In order to illustrate what I mean by referring to antiquated equipments that were replaced by modern equipments, I would

Fig. 1. Typical lighting units now in use in a large number of industrial installations.

like to refer to the accompanying illustration (Fig. 1). These atrocities are the kind of equipment that has been found in some of the older plants of Chicago. They are inefficient, do not provide an adequate degree of diffusion and, while I am not acquainted with the installations, I have no doubt that many of them are located improperly so that the direction of the light is not good.

Fig. 2. Eye shield for wide spacings giving productive intensities with 200-w, 300-w, and 500-w "C" lamps respectively.

Fig. 2, three modern, scientifically designed units which have been used in certain installations to replace those found above.

In *direction of light* for any useful accomplishment, we have the familiar illustration of the importance of having the light come over the left shoulder for writing, to the end that the right hand may not cast a shadow over the work. It is only that same idea

applied to all industries when we talk about the right direction of light in industrial lighting.

The right degree of *diffusion* is very important in industrial lighting. The drawing room in the speaker's home is lighted in such a way that when all lighting equipment is in service the diffusion is very high and the intensity is ample. A gathering in this room sometime ago engaged in a frolic in which numerous newly coined pennies were involved. This degenerated into a penny matching party, and it was quickly discovered that it was very difficult to distinguish between "heads" and "tails" under the lighting conditions which obtained. This illustrates the importance of securing the right degree of diffusion for any industrial purpose. Too much diffusion means poor discrimination when vision is dependent upon relief and shadows. Too little diffusion means glare, an unnecessary hampering of activities as well as damage to eyesight.

Absence of glare either from light sources within the worker's view or from polished working surfaces is of course essential. The avoidance of glare is closely connected with the right direction and the right diffusion of light. All these things—the right intensity, right direction, right degree of diffusion of light, and the avoidance of glare—are of the greatest importance in increasing production rate in the industries.

In this connection the Illuminating Engineering Society's service in preparing industrial lighting codes has been of very direct importance. These codes have been made the basis of regulations by several state labor authorities, and in addition have been promulgated during the war by the committee of labor of the Council of National Defense as the basis of lighting in plants engaged on war contracts.

In the newer equipments which have been put in industrial plants during war time, great advances over the older lighting equipments have been the general rule and the superior lighting which has thus been used in the great part of our rapidly expanding manufacture for war purposes has, therefore, promoted productivity. Thus the lighting industry has played a very considerable part in helping along the rapid production which was so essential to proper prosecution of the war.

In the course of the work of our committee with the Fuel Administration at Washington, this point came up. It chanced that the men at the head of the Bureau of Conservation in former times had engaged in industrial work and they appreciated this point. So, in spite of the great need for conserving coal, the United States Fuel Administration has been careful to avoid any curtailment of lighting in industrial work which might hamper production. In a letter from G. N. Allen, acting director of conservation of the United States Fuel Administration, is this expression of that view:

One particular point which is of great interest is the mistake which can so easily be made by failing to appreciate the impairment of health and

service which might result in too energetic an effort to save fuel by decreased lighting and such economy should not be proposed except in cases of the greatest emergency. We feel that this point can not be too thoroughly considered.

PROTECTION

The shameful abuse of neutrality privileges by Germany prior to our recognition of the state of war led to very early attention to methods of guarding important property, both public works and munition plants. Through the fortunate acquaintance of Dr. Hollis Godfrey, one of the commissioners of the Council of National Defense, with the Illuminating Engineering Society, The Bureau of Plant Protection, Military Intelligence, was early put into touch with the society and our committee had the privilege of laying out protective lighting installations for a number of important Government plants. That led later to preparation by the committee of a pamphlet on protective lighting, which was published by the general staff of the United States army. In that pamphlet instructions were given as to the principles and practice of protective lighting. An edition of five thousand copies was very quickly distributed and the printing of an additional seventy-five hundred was decided upon just prior to the signing of the armistice.

Edmund Leigh, chief of plant protection, Military Intelligence, says: "I will state flatly that I know of nothing that is so potential for good defense as good illumination and at the same time so little understood."

Plant protection, through lighting, not only means rendering the guard efficient at night, but it also means that effectual guarding of a plant can be accomplished with a smaller number of guards. This, especially in time of man power shortage, is a very important point. Wherever good protective lighting has been installed I know that the Plant Protection Bureau has felt very much easier about the plant.

SAFETY

In a recent paper by R. E. Simpson, engineer of the Travelers Insurance Company, it was pointed out that in 1910 a survey by that insurance company showed that 23.8 per cent of the accident claims filed were due to improper or inadequate illumination. Mr. Simpson states that improvement in lighting conditions since 1910 has unquestionably reduced that proportion, but he feels it safe to estimate that eighteen per cent of our industrial accidents today are due to ineffective lighting. On that basis he calculates that the services of one hundred and eight thousand men for one year are lost annually because the illumination provided is not adequate for safety. When we think of the services of 108,000 men per year, we immediately see how important a matter that becomes in time of war, both in economic and productive significance.

In New England, due to the very acute coal shortage last winter, curtailment of power use was carried farther than in many other sections of the country. And not all of the measures adopted appear to have been wise. Mr. Simpson has stated further

that in many factories excess of zeal caused the removal of lamps from sockets or the substitution of smaller lamps or the extinction of lamps in the less frequented parts of buildings. This resulted in a material increase of accidents. There is no doubt that adequate and good lighting is essential to safety.

CONSERVATION.

Conservation, it seems to me from a lighting point of view, can be considered under three heads. First, curtailment; second, improvement in methods; and third, elimination of waste. In the way of curtailment of course, the first thing that comes to our minds is daylight saving, which was put into effect in the spring and continued for seven months of 1918. The purposes of daylight saving were to reduce the use of artificial light and to promote gardening and recreation. It is my judgment that in all three particulars the advantages are very much smaller than were anticipated by the sponsors of the Daylight Saving Bill. We can note at the present time, however, that there was a material saving in coal through the reduction of artificial lighting due to the Daylight Saving Act.

The layman's mind, and I feel sure the thought of the Fuel Administration, was early directed to electric lighting as a field for curtailment because of its conspicuous character. The public generally has a mistaken conception as to the amount of coal involved in electric lighting. I presume it is fair to say that as much has been written about curtailment and conservation of coal through lighting as through all other opportunities for conservation put together. At least that is my impression, and yet electric lighting is responsible for only two per cent of the total coal consumed in the country.

The first direct Fuel Administration manifestation of a desire to save through electric lighting was our lightless nights, signless nights; later signless and show-windowless nights. These apparently had more than one object. There was a desire to save coal and in some places the desire to save generating capacity; but from the start the importance of electric lighting as an advertising medium appealed to everybody concerned and it was quickly recognized that there was no better way, and possibly there was no other equally as good, to preach conservation to the public than through the elimination of display lighting. As it is an economical method of publicity when in use, so it is an economical method of publicity for curtailment when eliminated.

The discontinuance in April, 1918, of the order eliminating the use of the signs brought to the Fuel Administration a flood of protests from all over the country. The public felt outraged that these signs should be allowed to burn when everybody knew there was a coal shortage and the Fuel Administration probably would have been compelled by the force of public opinion to put back the curtailment order on electric signs even if they had not thought it wise to do it themselves.

When a later order limiting the use of electric signs and later the use of show windows was put into effect, there occurred at Washington one of the most interesting developments, and I think one of the biggest endorsements for the value of electric lighting in publicity that I have ever heard of. A body of merchants visited Washington and said in effect to the Fuel Administration:

> If we must go without show window lighting part of the time to conserve fuel, those of us who are in the habit of keeping our stores open at night would prefer that you should let us burn our show window lights on certain nights of the week and let us remain open on those nights and close other nights, rather than to keep our stores open all nights of the week without any show window lighting.

Early in the summer of 1918 the Fuel Administration was beginning to think about indiscriminate curtailment of lighting. It crept into some of their pronouncements. We heard it in the talk of some of their people. Why shouldn't they prescribe the use of smaller lamps or the elimination of a certain percentage of lamps in order to save fuel? In a Fuel Administration article which appeared in the Literary Digest, the statement was made:

> Every home should eliminate at least one electric bulb in each room for the period of the war. At least one gas jet in every room should be dark for the period of the war.

Further than that, a tentative agreement was reached with the Hotel Men's Association under which every third lamp was to be removed from their hotels. Our committee had been doing a good deal of work for the Fuel Administration and I think had convinced the administration of its sincerity and its wish to help in all legitimate ways. It could not approve this sort of thing, and upon appreciation of our view the plan was dropped. We have not heard anything more about it as national conservation propaganda. I think the Fuel Administration people came to feel that indiscriminate curtailment of lighting would do more harm than good and would be unwise.

A few months later there was in contemplation a restrictive order under which the lighting of all semi-public places would be curtailed. That would effect, among others, stores, and our committee was called upon to give the Fuel Administration a basis for such an order. We were asked to state what, in our judgment, is the very lowest figure to which it would be safe to reduce lighting of semi-public places. Our recommendations were adjusted at a value of perhaps 40 per cent less than average practice and were of course calculated to meet a serious emergency. Due to the signing of the armistice and the improvement in the coal situation no action was taken in this direction.

Improved practice, which the layman does not think much about as a conservation measure, possesses large potentialities for conservation. If it is possible to substitute good, efficient illuminants for inefficient illuminants; effectual accessories for ineffectual reflectors, glassware, etc.; if it is possible to bring about a reduction of light sources so as to promote useful accomplishment wherever

work is done; if it is possible by painting ceilings and walls light colors to reflect a great deal of the light downward and conserve it; all these things can be applied not only economically but also as fuel saving measures. Anything that is done in that direction is wholly constructive. The Fuel Administration included improvement in practice in its later propaganda very effectually, and the War Industries Board in connection with the saving of steel in metal reflectors has promoted the cause.

In the elimination of waste, the most striking thing perhaps that has been done was the adoption by the United States Fuel Administration of an arrangement with the incandescent electric lamp manufacturers and with the central stations of the country under which the manufacture of certain types and sizes of carbon filament lamps was to be discontinued, and central station companies were called upon to discontinue the renewal of inefficient types of lamps. This program was accepted by the industry, and although the manufacturers have since been released, the good impetus given to better efficiency is by no means lost. This was a real conservation measure in lamp practice and I think bade fair to bring about as much advance in ridding the country of inefficient lamps as in normal times would have taken place in five or six years.

In connection with that development, it was found to the surprise of most concerned that the central stations of the country use inefficient types of electric lamps to a lesser extent relatively than does the rest of the country. There was a general impression that such was not the case. The associations of central stations have been hammering the inefficient lamps for years in an attempt to prevail upon their member companies to discontinue their use wherever possible. For example, here is an excerpt from a lamp committee report of a few years ago:

> Your committee again feels called upon to urge that member companies take more active measures to promote the further and more rapid substitution of Mazda for Gem and carbon lamps upon their circuits in order to remove any possible reproach of self-interest in failing to give to the public as promptly as practicable the full benefit of the improvements in the art and preserve to the Edison central station companies their reputation for giving to their customers the vest best service at the lowest prices.

That kind of hammering has proven very effective.

For example, taking the country at large for recent calendar years, the use of the inefficient types of lamps has been driven down from 59 per cent in 1912 to 13 per cent in 1917, and for a group of central stations, this has been brought down from 75 per cent to 10 per cent in 1917. The deliveries of lamps to the Commonwealth Edison Company in Chicago have made an even better showing in the elimination of the inefficient types, these forming 9 per cent in 1916 and 5 per cent in 1917. As a result, the United States Fuel Administration, starting out with the idea that most of their accomplishment in this directon would take place in modifying the practice of the central station companies, found that

on the other hand they would have to direct their attention more largely to other lighting interests.

One piece of work which our committee had a great deal of satisfaction in doing was the preparation of a pamphlet containing popular material on elimination of waste in lighting. It was called "Wartime Lighting Economies." The message that it carried was:

> During the war use daylight as much as possible, eliminate all wasteful methods of lighting and don't use artificial light wherever you can avoid its use.

The lighting industry has had to bear some very real burdens, and I think if I were a central station man I would be very proud of my industry. It has borne a burden of curtailed revenue without whimpering and has rendered a very real service while doing it. The industry's war committee, the National Committee on Gas and Electric Service, in Washington has a reputation second to none in service to the Government. I have been astonished in my experience in Washington at the confidence with which this committee is honored by Government officials. Everybody feels safe in going with troubles to the National Committee on Gas and Electric Service, knowing that if the committee can be of help to the officials of the Government that help will be forthcoming.

SUMMARY.

To sum up this part of our paper: Production is affected by the lighting. So important is this that in spite of the great need for conserving coal the Fuel Administration avoided restriction of industrial lighting. Protective lighting is vitally essential to guarding property upon which the successful prosecution of the war depended and was so regarded by Military Intelligence. Lighting adequate to safety best contributed to our war ability. Finally, conservation of coal was accomplished through curtailment, through improved lighting methods, and through elimination of waste.

CHANGE IN COMMITTEE'S VIEW THROUGHOUT THE WAR.

I should like to bring this discourse to a close with the recital of the change in sentiment which has taken place among the members of our Illuminating Engineering Society's committee in the course of its work for the Government on lighting economies. The constitution of that committee is varied. There are some electric and gas lighting men, some representatives of manufacturers who are interested in lighting. There are also some laboratory research men, some testing men, a representative of the National Bureau of Standards, an oculist and almost every interest which from any point of view has to do with lighting. I think I am right in saying that at no time in the course of our work was there among these varied interests represented, any material difference in judgment of any of the problems of curtailment which we discussed. We started on this matter of lighting curtailment somewhat in a spirit of protest. We were inclined to dwell on the fact that electric

lighting consumes only two per cent of the country's coal and that in expecting electric lighting to supply more than its share of the conservation of coal to be effected, the Fuel Administration was not quite fair. When the lightless nights came along, some of us did not at first think that the ruling was quite fair and right; after all there was very little coal involved in comparison with all the damage the curtailment did, etc.

I remember with how much interest we put together such things as the following:

ANNUAL RATE OF COAL SAVINGS IN ELECTRIC LIGHTING

(U. S. Fuel Administration Estimates)

Daylight saving	1,000,000 tons
Lightless nights	1,000,000 tons
Limitation of manufacture and distribution of inefficient lamps	1,000,000 tons
Anti-waste campaign	*1,000,000 tons

Four million tons to be saved! And the total consumption of coal in electric lighting we estimate is twelve million tons. One quarter of the total coal consumption in electric lighting to be eliminated!

There is a statement by the conservation division of the Fuel Administration to the effect that twenty-four million tons of coal is wasted in the homes by reason of excessive draft in heaters, and we compared that with twelve million tons of coal consumed in electric lighting. There are many other similar comparisons all of which would tend to show that electric lighting is such a small coal consumer that one ought not to expect a huge saving to be effected through conservation in the electric lighting field.

Here is a quotation from a report which our committee had all but adopted on one occasion many months ago when the protest spirit ran high. We did not adopt it, however.

> We desire to express our profound conviction that curtailment directed for its psychological effect in view of its dangerous and meager accomplishment in fuel saving is an unwise and mischievous step.

As we went on with our work, particularly as we worked with the Fuel Administration at Washington, we came to feel that after all that was not the way to serve the country and we got quite away from that point of view along in the summer of 1918. The statement that we made to the Fuel Administration in place of the one that I have just read was finally as follows:

> The present proposal is opposed to efficiency in transaction of business, tends to lower morale, and does not teach good practice. It will probably have certain detrimental effects and can be supported only as an emergency war measure, of the necessity of which the Fuel Administration is the judge.

And then we began to view the publicity to be gained through curtailment of lighting, the means it offered for advertising conservation to the public, as an opportunity to serve. We were getting more of the war spirit. We were getting into harness as real patriotic citizens at that time. Bernard Shaw with his usual cynicism

*Not published.

and error has said that "every profession is a conspiracy against the laity." I think we got to the point where we were just about as far away from this definition of Shaw as men could be. We were for the country in all of the work done for the Government Bureaus at Washington.

In August, 1918, P. B. Noyes, director of conservation of the Fuel Administration, made this statement to a few of us, which about a month later he repeated before a convention of stationary engineers at Cincinnati:

> We cannot fill Pershing's order in full because the United States cannot make sufficient steel this winter. A shortage in steel results almost entirely from lack of coal. Keep this in mind and then look forward to the events of the coming spring. We shall have the drive. We shall succeed in it, but some time in February or March, or whenever the time has come, General Pershing will sit down with a pencil in hand and will figure up the exact deficit in the filling of his orders for munitions. With military formulas now well recognized, he will figure in place of those munitions how many extra men must be put into the battle to be killed. This is no fanciful statement. It is now possible to treat in any aggressive movement the question of munitions or casualties as interchangeable quantities. So many thousand American youths must be thrown into the hopper for every thousand tons of munitions which are short.

That statement bowled us over. We did not know that Mr. Noyes' interpretation was correct, but Mr. Noyes was in a position of authority not only as representing the Fuel Administration, but also as connected with the War Industries Board. He was there to speak for the Government on such matters and that was his statement. We could do nothing less than accept it, and I think from that time the men on our committee became amateur fuel administrators. Their first thought was how could they help to make lighting yield coal savings, and help with this steel problem.

We wound up the wartime work with a clear conviction that everything which we attempted should be undertaken with the following considerations in mind, and in the order in which I shall state them: First, the promotion of the war ability of the nation; second, the promotion of public welfare; third, the conservation of the lighting industry; fourth, the conservation of other industries. That order, with the promotion of the war ability of the nation at the head, was the final conviction of our men and it was in that spirit that the greater part of our work was done.

Reinforced Gypsum

By W. A. Slater
Engineer-Physicist, U. S. Director of Standards, Washington, D. C.

DISCUSSION.*

Mr. Locke: What was meant by dry gypsum and gypsum containing different proportions of water, and how was that determined? Is dry gypsum that which contains no water except the water of crystallization, and is the other the case where water is added to mix the material above that that is required for the water of crystallization?

Chairman: Possibly it might be well for us to get a number of questions before us and then Mr. Slater can give an answer to the various questions that are asked.

Mr. Blaylock: I recall that about three years ago, in designing a building, a salesman for the gypsum company tried to induce me to use the gypsum in order to carry the tar and gravel roof, but the special requirements were such that if I had made the design accordingly I would have eliminated all other competitors. What is the commercial value of gypsum when compared to reinforced concrete in building roofs? I have often heard the statement made that you can greatly reduce the loading, and thereby reduce the amount of structural steel required. I have worked on the idea that gypsum is used principally for partitions in building which were easily removed about the first of May. My ideas may be erroneous, but what is the commercial value of gypsum besides what you get in the form of partitions? In designing with this material what factors of safety would be required and what stresses may I use?

Member: It was stated that after a dryness of one hundred per cent the stresses decrease. What temperature is enough to cause that decrease from one hundred per cent dryness?

Member: What action would take place if reinforced gypsum were subject to contact with steam such as you would get in heating plants, or boiler houses where the under side of it would come in contact with steam? Would there be additional corrosion, and would there be any disintegration of the gypsum itself?

Mr. Dahlstrom: There is one further question in regard to the moisture that I believe has not been covered. After it has been put in final place in the structure, is there any probability of the gypsum absorbing moisture and its strength being affected thereby?

Chairman: Mr. Slater suggested there could be some discussion tonight if there were any present who have had practical experience in the use of gypsum. I am quite sure we have here some who have had some practical experience which will greatly

Editor's Note: The original paper by Mr. Slater was published in the September issue of the Journal as an advance paper, and read at the meeting of October 13.

assist us in understanding this rather new and very interesting material of construction.

Mr. Lacher: I can make one answer to Mr. Blaylock about the utility of this material for different purposes. Roundhouse roofs have given trouble with reinforced concrete of the ordinary slab of concrete in northern latitudes, because of the high amount of condensation which takes place on the surface of such roofs during cold weather. Because the concrete is relatively a good conductor of heat, it becomes practically as cold on the inside as it is on the outside, and in roundhouses where the percentage of moisture has been high, there have been cases where there was much condensation on the underside of those roofs. That has led in some cases to the use of the concrete tile form of construction in which you get the relatively small "T" beams interspersed with a tile in between. That has been used to quite an extent in building construction. This, of course, has done away with that trouble to a considerable extent. That condition is what suggested the use of gypsum as a roof construction material, and it has been so used.

One prominent case of this kind is in a roundhouse built within the past year on the Pittsburgh & Lake Erie. This was built of unit slabs of reinforced gypsum of Burnside manufacture, and set up in place. They made no attempt to make the slabs fit exactly to the location. The slabs were laid parallel with the center line of the stall, so the stalls of a roundhouse being shaped like pieces of pie, gave triangular joints where the gypsum slabs came up to the joint between stalls, and that space was filled by sawing up short pieces of un-reinforced gypsum to fit into the triangular spaces. That material, by the way, was purchased on the specification for certain strength, either dry or wet; that is, after a certain length of time of submerging in water. The manufacturer was able to meet those specifications. The specimens after being submerged in water for such a period gave the satisfactory strength test.

Mr. Slater: Answering Mr. Lacher's question about dry gypsum: By dry gypsum is meant hydrated gypsum from which all the water in excess of that required for complete hydration has been evaporated. I think that your understanding of it is correct. It is found, I might add here, that out of the total amount of water added to the calcined gypsum only enough is taken up in the process of hydration to change the material to $CaSO_4—2H_2O$. Knowing from analysis the amount of water already present in the calcined gypsum and the weight of the impurities which absorb no water (see Table 10 p. 437), a calculation can be made which gives with great exactness the amount of water which will be taken up in the hydration of any given weight of calcined gypsum. Knowing the weight of gypsum in any batch and the proportionate amount of water together with the actual weight of the wet specimen it has been possible to determine in advance the weight which any specimen would attain when dry. This method has been used in de-

termining the percentages of dryness reported in the text of this paper.

Mr. Slater: Mr. Blaylock asked regarding working stresses and factors of safety. In the tentative report of Committee C11 of the American Society for Testing Materials, the allowable stress for steel in reinforced gypsum is 16,000 pounds per square inch, just the same as is widely used in reinforced concrete. Any saving in steel would therefore be due entirely to the saving of the weight in the structure. The recommended allowable stress in gypsum is .22 of the ultimate strength of the gypsum when dry, or .44 of the strength of the wet specimen. That assumes that the strength wet is about half of what it is when it is dry. This would give a factor of safety of about 2½ when the specimen is thoroughly saturated. That is based on the compressive strength of the gypsum. If it is loaded thoroughly dry the factor of safety based upon the allowable compressive stress would be approximately 5, but of course failure would occur due to the stresses in the steel exceeding the yield-point, so the factor of safety based on the stresses in the steel could not be much over 2½. There is a question of deflection which has not been thoroughly explained and threshed out, and it is one of the things which probably is going to require more investigation as to the conditions of construction under which there is danger of getting deflection that is objectionable for other reasons than the strength. I feel satisfied on the factors of safety provided in the recommendations referred to, so far as strength is concerned, but there are other things that enter which may cause a modification of the allowable stresses later.

I would like to mention, since the question of partition tile is brought up, that the gypsum that we are speaking of is very different in physical properties from the partition tile referred to. The partition tile is made light. That is one of the necessities of the case, or one of the advantages of the form of construction, rather. It is not usually called on, in fact, never called on, to carry any load other than its own weight, and the strength of the tile is not sufficient to permit them to carry any appreciable load other than their own weight. They must not be confused with the gypsum referred to here.

I showed a very large range of strength between gypsum which is as dry as it could be mixed, and the strength of gypsum which is very sloppy. As I understand the manufacture of the gypsum partition tile, it falls at a position at the lower end of that curve. It is of almost a soupy mixture. These tests have not covered that end of it, but I know from the weight of the partition tiles that they must have a percentage of water which would place them there on the curve.

Question: What is the weight per cubic foot of high strength gypsum?

Mr. Slater: It will be probably 75 to 80 pounds per cubic foot. Eighty pounds represents a quantity of water which probably is a

little smaller than would be practical in operation. You probably would have to use an amount of water which would bring the weight down to about 75 pounds.

The question was asked about the temperature which would cause a decrease in the strength. We have not determined that exactly. One diagram (Fig. 17 p. 427) showed that at 140 degrees temperature there was after a considerable length of time a loss in strength, due to the temperature. I don't know how much lower temperature than that would cause a loss in strength. We do know that at 100 degrees there was no indication of a continuous loss of strength. One of the curves indicated that with gypsum dried at 100 degrees a higher strength was obtained immediately after it had been dried out, but that excess strength was soon lost, and after it had an age of probably thirty days the strength had fallen to that of gypsum dried at about ordinary temperatures,—without any definite indication that it would continually lose in strength after it had come down to that average.

With regard to the effect of contact with steam, I should say that that would depend upon the quantity of steam. There are given in the paper the results of tests of specimens taken from a factory at Oakfield, N. Y., of the United States Gypsum Company of tile which had been in use for four years. I do not know how much steam came in contact with those tile, but an examination showed very little corrosion, and the same thing might be said with regard to the tile that were taken from the roundhouse in Iowa. I believe it was at McGregor, Iowa. This was reported by Mr. La-Fountain of the Chicago, Milwaukee & St. Paul Railroad Company, and with his permission I quoted on page 436 from a letter of his regarding those tile. He said there was no indication of serious corrosion at all in any of the tile taken from that roundhouse, and that the corrosion was less with deeper imbedment of the steel in the gypsum. I should suppose that in a roundhouse where there were sulphur fumes, there would also be steam, although his letter did not cover that case as to how much steam there was or whether that would be an important consideration in this case.

I believe there was another question about the absorption of moisture. I think I have covered that in what I have said about the other case. The showing of the tests is that gypsum absorbs moisture very rapidly if there is any moisture to absorb. How much is required to reduce the strength I cannot say, but the indication is very clear that it will not under any conditions (except saturation such as is obtained by complete immersion for six months or more), lose more than about half of its strength, and the recommendations are based on the assumption that there might be under some extreme conditions a loss of half of the strength. I am satisfied that these recommendations will give safe design so far as the strength is concerned.

Mr. Parsons: We once had some un-re-enforced gypsum slabs on two buildings at what is called the "pure plant" of the Peoples'

Gas Company and the Drainage Canal, and while I don't know all the reasons why they were used, the placing of those slabs and perhaps the defeating of some of the engineering problems by erection might be interesting. One of the reasons for adopting the gypsum slab was that we could use a hard tile roof, a terra cotta tile roof slab, on this gypsum slab, and nail it down into the slab. They wanted the tile roofing, and instead of putting a wooden roof the gypsum slab was suggested and then the steel was designed for that, the slabs were 16 inches by 36, I think. It was a regular pearline roof, and were placed running from the peak of the roof down to the eaves to support these slabs, so evidently there wasn't much saving in steel. The pearlins were holding up the gypsum slab and the roofing tile. But in placing those slabs we had to be very careful, as they were not re-enforced, and the breakage was considerable; and then the factory markings, on the slabs, were on both sides, so that when the roof was up it was not presentable at all from the inside, so we had to paint the under side of the gypsum slab. That probably kept the gypsum from absorbing moisture.

In these buildings are stills in which there is a great deal of steam used, and at times the steam escapes and goes up to the roof. There are plenty of openings to take it away, but the steam is often in contact with the gypsum, but the paint was there to cover up certain markings, so the effect of absorption could not be noticed in that case. This plant was built two years ago and I have asked some of the People's Gas people officials and they say that the roof is in very nice shape and everything is fine; the nails have held in the gypsum, and they could not want a better job. Those are just a few observations that may help in discussing the subject.

Mr. Slater: Did I understand that the slab were un-re-enforced?

Mr. Parsons: I am sure that they put some rope right across.

Mr. Slater: May I ask what the span was in that case? I am very much surprised that any kind of a gypsum un-re-enforced slab should be used for roofing purposes. I wouldn't want to trust my weight on a gypsum slab of any appreciable span any more than I would on a thin concrete slab of any appreciable span. I never have known of such practice and would not approve it for even the shortest span gypsum roofing tile of which I have any knowledge.

Mr. Parsons: They were 16 by 36 inches, as I remember it. The T irons were placed in a vertical position, that is, from the peak right down. We slid the slabs down. They were supported on the sides, but not across the seams. The men walked on them and worked around them.

Mr. Erickson: I know of a style of roofing structure in which they used re-enforced concrete rods with a span between girders,—a sort of a suspension rope,—and then pour a roof slab over this material, and it was recommended for a number of different structures. Last spring we had occasion to try to design the roof of a theater to cut down the price as much as we could. If we ran the

suspension rope of re-enforced steel from truss to truss, we found that we would save quite a bit on the roofing steel. I don't know exactly what the percentage was, but there was quite a saving in the entire weight of the structure, but if we ran our bracing between the trusses as is required by the city ordinance, and ran the re-enforcing ropes parallel to the trusses, we found that the bracing to take care of the tension in the end panels and the various little details that would be required, would cost enough to make the construction uneconomical. I don't have the exact figures with me, but we went into that very carefully. It seemed a very good style of construction for a theater building, where the rope was run from truss to truss and using a sag. I don't know what the percentage of the sag was.

Member: In connection with the temperature: It appears from the statement (see p. 427 and p. 602) that should a fire occur where the gypsum is placed in a position to be used as a fire-proofing material also, that it wouldn't stand up very readily or wouldn't last very long there, because it doesn't take much of a fire to create a temperature of 140 degrees, in fact, very little. I think any sort of a blaze would soon reach four or five hundred degrees of temperature.

Mr. Slater: That brings up a very important point, and one of the strongest features of gypsum. I have not discussed the fire resistance question at all in this paper. Of course you are right in stating that 140 degrees temperature is reached in a very short time in any fire, but the important property of gypsum is that the water of crystallization that is present prevents the rise in temperature. The fire may destroy the strength of the gypsum on the exposed face, but the large amount of water of crystallization which has to be evaporated before there can be an increase of temperature above 212 degrees protects anything on the opposite face from damage, due to a fire. The long continued effect of a fire would, of course, finally destroy the strength of the gypsum, but this destructive process is slow and if the structure has served the purpose of protecting the goods on the other side of the gypsum partition or floor, it has accomplished an important purpose and the duration of the fire would not, in most cases, be sufficient to destroy the coating over the steel in a re-enforced gypsum member.

Mr. Robinson of the Underwriters Laboratory recently told me (He is not in any way interested in gypsum other than as he is interested in fire protection) of a fire test of an elevator casing at the Underwriters' Laboratory, in which a six-inch partition of gypsum stood up while the concrete lintel on the top of this six-inch partition of gypsum was fused and ran down over the gypsum. Bricks in the structure also were fused. It is entirely possible that the strength of the gypsum on the outer surface was destroyed, but there is no doubt that it was still very effective in retarding the entrance of the heat from the fire to the center of the gypsum more than ever. Fire resistance is one of the strongest points in favor of the use of gypsum.

Proceedings of the Society

Meeting No. 1052, November 3, 1919.

This was a general meeting of the Society, the president presiding. There were 107 members and guests present. The subject under discussion at this meeting was a tentative report of the development committee of the society. E. T. Howson, chairman of the committee, presided during the discussion. Development plans for increasing activities of the Society were presented. The committee had under consideration an increase in committee work of the Society. The plan suggested was as follows: Members of the Society should form groups for study and research in various engineering subjects. They should meet from time to time and gather together all the data available on the subject in hand. When a complete and exhaustive study of the subject had been made, the report of the committee should be published in the Journal of the Society or in text book form. Later developments on the subjects should be taken care of by publication of additional information from the committee. The membership in attendance seemed to be much in favor of this method of procedure and the committee was advised to prepare further plans for this work.

It was the consensus of opinion that the Society should hold luncheon meetings, preferably once a month. A speaker of national or local prominence should be obtained to address the members on these occasions on subjects not necessarily related to engineering. It was decided that meetings of the Society should begin at seven in the evening instead of eight o'clock. It was also agreed that meetings should close not later than nine-thirty. The use of the library in connection with the technical affairs of the Society came in for broad discussion. Several members advocated that periodicals other than those of a technical nature should be included in the list of magazines and journals on file in the reading room. All were in favor of making various changes in the arrangement of the library when the necessary space can be obtained to permit such a move. The discussion at this meeting was a result of the activity of the Society during the membership campaign. The opinions of new as well as old members were asked for in regard to the future policy of the organization. The meeting was adjourned at 9:30 p. m.

Meeting No. 1053, November 10, 1919.

This was a meeting of the Bridge and Structural Engineering Section of the Society, G. A. Haggander presiding. The following officers were nominated for the coming year: Chairman, A. W. Dilling; vice-chairman, J. E. Love; director, H. H. Hadsall. Andrews Allen, M. W. S. E., past president, presented a paper in description of the Kathleen mine plant at Duquoin, Ill. Slides illustrating the mechanical equipment of the mine were explained and displayed in detail by Mr. Allen. New features in mine construction and plant equipment were brought out by the speaker. There were 90 members and guests present. The meeting was adjourned at 9:30 p. m.

Meeting No. 1054, November 12, 1919.

There was a meeting of the Gas Engineering Section of the Society. There were 60 members and guests present. Officers for 1920 were elected as follows: Chairman, C. C. Boardman; vice-chairman, R. B. Harper; director, three years, C. W. Bradley. H. H. Clark, chairman of the section, presented a paper on "Engineering in the Gas Industry" which was illustrated with slides. He pointed out how application of engineering methods to the industry has brought about many improvements in the equipment used for consuming gas. The meeting was adjourned at 8:30 p. m.

Meeting No. 1055, November 17, 1919.

This was a joint meeting of the Mechanical Section and the Heating and Ventilating Engineers of the Society, there being 120 members and

guests present. The following officers for the section for 1920 were elected: Chairman, A. L. Rice; vice-chairman, J. L. Hecht; director, three years, F. O. Lindberg; director, two years, G. E. Pfisterer. The subject for discussion was "Purchase of Coal on Specifications." John Howatt, chief engineer of the Chicago Board of Education, presented the questions from the viewpoint of the consumer pointing out the advantages and disadvantages of common methods of purchasing coal and the benefit to be derived by purchasing from specifications. Edward Taylor of the Crerar-Clinch Coal Co. explained the dealers' and producers' viewpoint of the question. This subject brought out a lengthy discussion which was participated in by many of those present. The meeting was adjourned at 10:15 p. m.

Meeting No. 1056, November 24, 1919.

This was a joint meeting of the Electrical Section, W. S. E., the Chicago section, A. I. E. E., and the Illuminating Engineering Society and the Chicago section, A. S. M. E. The following nominations for officers of the electrical section, W. S. E., were made: Chairman, A. F. Riggs; vice-chairman, C. A. Kellar; director, three years, C. A. Kellar. The general subject of the meeting was "Industrial Economics." Harold Almert, consulting engineer, Chicago, who presided, presented a paper on "Industrial Economics." Edward Tillson, testing engineer, Commonwealth-Edison Co., illustrated his paper, "The Reaction to Intensive Lighting," with slides, bringing out the results obtained in manufacturing organizations by installation of lighting facilities for the direct benefit of the employes. George H. Jones, power engineer of the Commonwealth-Edison Co., presented a paper on "Electrical Power as a Factor in Effecting Economies and Increasing Production." His paper was illustrated with slides. Adjourned at 9 p. m.

EDGAR S. NETHERCUT, *Secretary.*

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